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MEMOIRS AND PROCEEDINGS

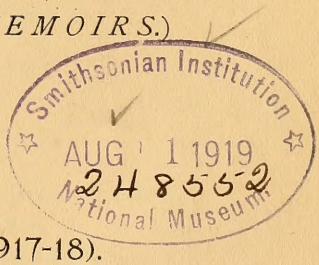
OF THE

MANCHESTER

LITERARY & PHILOSOPHICAL

SOCIETY.

(*MANCHESTER MEMOIRS.*)



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NOTE.

THE authors of the several papers contained in this volume are themselves accountable for all the statements and reasonings which they have offered. In these particulars the Society must not be considered as in any way responsible.

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PRESIDENTIAL ADDRESS.

By The President,

William Thomson, F.R.S.E., F.I.C., F.C.S.

October 2nd, 1917.

I thank you for the great honour you have conferred upon me by electing me as President of this important and historic Society, and I propose in my address to try to briefly recapitulate its history, and to dwell on the extraordinary importance of the work which has been done in it: work which has created two of the most important of the Sciences, viz., Chemistry and Engineering, and which to-day form the foundations of the work in these Sciences in every country in the world. The labours of Dalton and Joule have rendered their names immortal and have added lustre to the Literary and Philosophical Society of Manchester, with which they were both so closely associated. These, however, form only a part of the classical work which has emanated from the Society.

The date of the foundation of the Society is given as 1781 (136 years ago), but according to Dr. Angus Smith it was closely associated with those who were educated in or connected with the Warrington Academy, which was founded 24 years earlier (about the year 1757). The Warrington Academy was founded by a small body of religionists, and was one of the first teaching institutions of the day. When the Warrington Academy was dissolved, it was virtually continued in Manchester as "The Manchester Academy." It had many eminent men as teachers, among whom may be mentioned Jaen Paul Marat, who was believed by some to be the great French revolutionist who was put to death by Charlotte Corday. Marat spent eleven years of his life in England about the time of the Warrington Academy, and it is believed that he taught languages there. He published "Essay on Man" in London in 1773, and received his Court appointment in France, 1777. He is believed to have been in practice as a well-known doctor in London in 1776.

Joseph Priestley came to the Warrington Academy in 1761 as a teacher of languages and Belles Lettres, and was subsequently a member of this Society (elected 21st October, 1791). At the Warrington Academy he was induced to take an interest in Science, and soon afterwards published a paper on "A History of Electricity." At that time it seemed questionable whether Warrington or Manchester would prove to be the more important

of the two towns. The word Oxygen was unknown; the name which was used for it and other elements was "dephlogistigated air." At this time Priestley was resident in Warrington, and he it was who discovered Oxygen on the 1st of August, 1774, a discovery which enabled Lavoisier to put forward the true theory of Combustion. Lavoisier was elected an Honorary Member of this Society on the 2nd April, 1783.

One of the first Presidents of this Society and the founder of it was Dr. Thomas Percival, who was a pupil and friend of Priestley, and who became an eminent physician in practice in Manchester. The first meetings of the Society were held at his house, where meteorology, the sun, moon, and the weather were frequently discussed. I can remember a hundred years later, when Mr. Binney and Mr. Baxendall were active members, that these topics formed frequent subjects of discussion.

Some idea of the aims of the Society may be gathered from a resolution which was passed in its early days: "That a Gold Medal value seven guineas be given to the author of the best experimental paper on any subject relative to Arts and Manufactures read at the ordinary meetings before the last Wednesday in March, 1786.

Under the heading of "Regulations" of that time, the following occurs, which may be taken as a useful suggestion to the members of to-day:—

> *Regulation VII.*—The regular attendance of members being essential to the prosperity and usefulness of the Institution, that if any member shall absent himself during the space of three months from the meetings of the Society, notice shall be sent to him at a quarterly meeting that the Society considers his absence as a mark of disrespect, and that a more punctual observance of the laws is expected from him.

and also the following:—

> *Regulation VIII.*—To encourage the exertions of young men who attend the meetings of the Society as visitors, that a Silver Medal, not exceeding the value of two guineas, be given annually to any one of them under the age of twenty-one years, who shall, within the year, have furnished the Society with the best paper on any subject of literature or philosophy, and that such adjudication shall be made by the Committee of Papers.

The Society was to consist of fifty members, all of whom had to be distinguished by literary or philosophical publications.

Manchester at this time, and mainly through the influence of this Society, drew public attention to Sanitary matters and influenced the formation of a Board of Health in 1796. A letter addressed by Dr. Haygarth, of Chester, to Dr. Percival, of

Manchester, published in the Transactions of the Society is of interest at the present time, in which it says:—

> During this war (1796) many new-raised regiments coming from Ireland with numerous recruits taken out of jails remained in Chester for a few weeks after their voyage, were ill of putrid fever.

It was decided to put them together in special hospitals. Some authorities doubted the wisdom of this, thinking it would have the effect of spreading the disease throughout the town, but the wisdom propounded at the time in Manchester prevailed, and the value of Isolation Hospitals has been established. Tobacco smoking is also advocated as a disinfectant and preventive against fever. The purity of the atmosphere was then (1796) much discussed. Dr. Percival regarded with great uneasiness the fact that no less than 300 tons of coal were burned in Manchester per day—90,000 tons per annum. One can imagine his astonishment if he had lived to-day to know that somewhere in the region of 5,000,000 tons of coal are burned in Manchester per annum.

Dr. Percival commenced his sanitary work in 1773, and published proposals for the establishment of a judicious and accurate register of the births and deaths in every town and parish. He says in Stoke Damerel, in Devonshire, 1 person in 54 died annually; in Vienna and Edinburgh, 1 in 20; in London, 1 in 21.

The first President of the Society was Mr. James Massey, a man of wealth and a philanthropist, along with Peter Mainwaring, M.D., and the first Secretaries were Thomas Henry and George Bew.

During the second year of the Society James Massey and Thomas Percival, M.D., were Presidents, and they continued together in that capacity from 1782 till 1787. Then James Massey alone was President from 1787 till 1789, followed by Dr. Percival from 1790 till 1804. A marble tablet is inserted in the wall of the Society's room behind the President's chair in his memory, and his portrait, presented by Mr. F. Nicholson, hangs on the same wall. The name Percival survived in the grandson of Dr. Percival as Sir Percival Heywood (1881), whose grandfather married a daughter of Dr. Percival.

The first volume of the Society's *Memoirs* was published in 1785 and was dedicated "by permission to the King." A short summary of some of the papers appearing in these memoirs may be of interest. Dr. Bell read a paper 16th May, 1781, entitled: "Some remarks on the opinion that the animal body possesses the power of generating cold." This referred to the

fact that some men had remained in a room, the temperature of the air of which was far above that of the human blood for half an hour, the heat of their bodies did not increase more than three or four degrees.

Another paper appears by the Rev. Samuel Hall, M.A., on "An attempt to show that the beauties of nature and the fine arts has no influence favourable to morals." This was a reply to a paper read before the Society by Dr. Percival.

Dr. Peter Mainwaring, one of the first Presidents, was an eminent physician in Manchester, who presented to the Royal Infirmary a collection of books and book cases, which formed the nucleus of the present library. He was elected a member of the Society in 1781, and died at the age of 91 in the year 1785.

In 1773, it may be noted, that the inhabitants of Manchester and Salford numbered 19,839; to-day they are about fifty times that number.

Dr. William Henry, F.R.S., was elected a member of this Society on the 29th April, 1796. He was assistant to Dr. Percival. He was engaged at the Manchester Infirmary under Dr. Farrier, another famous physician, and is perhaps best known as having introduced calcined magnesia as a medicine, which is still known as "Henry's magnesia."

Dr. Alexander Eason was born in 1735, and became a member of the Society about 1781. He was a member of the medical staff of the Infirmary. He lived in Lever Street, Piccadilly. It is recorded that he bought the house and grounds for £800, which 80 years later produced an income of £1,600 per annum. A tablet was erected to his memory in the Manchester Cathedral, contributed by penny subscriptions from the poor. He met with an accident through the stumbling of his horse whilst on his way to visit a patient, Miss Yates, aunt to Sir Robert Peel, which caused his death at the age of 61.

John Massey was elected a member in 1781 (and was one of the first presidents, already mentioned). He read a quaint paper before the Society on the "Manufacture of Salt-Petre from the decomposition of dung heaps when mixed with wood ashes."

Charles White, F.R.S., author of "Gradation in Man," a famous surgeon, was one of the first Vice-Presidents. He followed his father, Dr. Thomas White, and was a fellow student and friend of John Hunter. There is a letter published from his son, Mr. Thomas White—also a Medical man—dated

Paris, 29th July, 1784, in which he describes a visit he paid to the subterraneous caverns at Paris, commonly called "The Quarries," which, according to his description, appeared like an underground city, the streets being formed by the removal of rock in long lines. The stone for building overhead was removed to a depth of 360 feet and for about two miles. These quarries were kept secret in Paris. They were commenced by Louis XIV. in 1667. Mr. Thomas White says all the Faubourg St. Jacques, Rue de la Harpe, and Rue de Tournon stand over these ancient quarries, supported by pillars and arches, and on occasions some parts of the surface have collapsed.

I may allude in passing to other members of this Society. The Rev. Dr. Thomas Barnes, F.R.S., elected 1781, Minister of the Unitarian Chapel in Cross Street for 31 years, succeeded by the Rev. John Robberds, elected a member in 1811, who was succeeded by the Rev. William Gaskell, elected 1840, better known perhaps as the husband of Mrs. Gaskell.

The Rev. George Walker, F.R.S., elected 1782, followed Dr. Percival as President in 1805. He was Mathematical Teacher at the Warrington Academy in 1772, and subsequently teacher of mathematics at Durham, at a salary of little more than £40 a year, which owing to the poverty of the institution was not paid in full.

Thomas Walker, elected 1790, was President of the Manchester Constitutional Society. He, in that capacity, communicated with the Patriotic Societies in France for establishing correspondence with the Manchester Society for the good of humanity. These proceedings attracted the attention of Mr. Burke, who, in his speech in the House of Commons, April 30th, 1792, denounced Thomas Cooper and Thomas Walker as consorting with traitors and regicides in the Club of the Jacobins in Paris. Walker's house in South Parade, St. Mary's Parsonage, was attacked by the mob and he fired on them. He was tried with others at Lancaster on a charge of having conspired to overthrow the Constitution and assist the French in their threatened attack on this island. He was acquitted, and triumphantly returned to Manchester on the 3rd March, 1794.

Mr. Hutchinson, elected 1801, was Dock-master at Liverpool, and wrote chiefly on meteorological subjects.

One of his papers is entitled "Meteorological Observations from 1768 to 1793."

John Dalton, elected 1794, was President of the Society from 1817 till 1844, during 27 years. In 1795 comes his first paper, "An Essay on the Vision of Colours." Then follow papers on

"Evaporation and Springs," "The Power of Fluids to Conduct Heat," "Experiments and Observations on Heat and Cold Produced by Mechanical Condensation and Rarefaction of Air," "Experimental Essays on the Constitution of Mixed Gases," and "Meteorological Observations made at Manchester." John Dalton was born at Eaglesfield, in Cumberland, 5th September, 1766. His father was a weaver of woollens in his own cottage. He was taught at a school of the Society of Friends, to which the family belonged. So quickly did he acquire knowledge that he was appointed at the age of 12 to conduct the school at which he had been as a scholar. At 14 he went to Kendal as assistant in the school of his cousin. His first attempts at writing were sent to *The Gentlemen's Magazine*, and he received prizes for the best answers to the mathematical and other questions propounded in that periodical. When in Kendal he made the acquaintance of Mr. Gouch, an eminent scientist, although blind from birth. Through his influence he obtained in 1793 the position of Teacher of Mathematics and Physics in the New College, Manchester (which was a continuation of the Warrington Academy), and afterwards he spent the greater portion of his life in the service of this Society. As soon as his great abilities were recognised he was appointed Secretary of the Society with his laboratory in the present building. He afterwards was appointed President, and for about forty years, till his death, he was the sole manager of the Society's affairs.

In his examination of the mode of analysing air he discovered that in using nitric-oxide to absorb oxygen it required 72 measures to absorb the oxygen from 100 measures of air; and if he used more than that of nitric-oxide, or more of air, he got an excess of one or the other. This led him to the consideration of definite quantities of elements or compounds uniting with each other, and he argued that if a pound weight of one material, combined with a pound weight of another, that half a pound would combine with half a pound, and so that this relative proportion would continue to the smallest conceivable weights. This gave him the idea of the Atomic Theory. He then represented these by balls, assuming a hydrogen ball to be black and an oxygen ball white; then water would be represented by one black ball joined to one white ball, and no half ball can be used and no confusion of fractions. This was found to suit all the known facts in chemistry. If the quantity of water weighs 9, the hydrogen would weigh 1 and the oxygen 8. The Atomic Weight of hydrogen was therefore taken as unity, and the oxygen as 8, and the balls always represented these relative weights, and the chemical combinations always took place in these definite weights for each element. Thus Iron was found to be 28, and in combining with oxygen it took up 8 parts or multiples of 8,

and thus the atomic theory took root, and on it now hangs all the fruit of chemical science.

In 1833 a pension of £150 was conferred on Dalton by the Government, afterwards increased to £300. He lived in comparative poverty most of his life. Dalton was colour-blind. He was a rather tall and powerful man. He remained a bachelor all his life. He died 27th July, 1844, aged 78 years.

In passing, I might incidentally mention other papers which appear in the *Memoirs* of the Society.

Dr. Anderson (the founder of the Andersonian University of Glasgow) contributes a paper on "A Universal Written Character," which calls to mind the work of Alexander Melville Bell, of Edinburgh, on "Visible Speech," and of his illustrious son Graham Bell, who gave us the telephone and the photophone.

In 1801 Thomas Hoyle, Junior (originator of the famous print works of that name), gives a paper on "The Oxygenated Muriate of Potash" (the potassium chlorate of to-day).

In 1790 James Watt, Junior, son of the great James Watt of steam engine fame, was Secretary of this Society along with Dr. Ferriar. He was elected 1789.

Reference may here be made to John Kennedy, who came to Manchester from Scotland, was elected in 1803, and remained a member until his death in 1855. From 1822 his house was a prominent one, standing on the south side of Ardwick Green. He was a maker of cotton spinning machinery, and the first cotton spinner whose works were driven by steam power. He invented the differential motion in the Jack frame. His daughter married Edwin Chadwick, C.B., the father of sanitary reform, who was born in this district.

Peter Ewart, elected 1798, bridged over the time from Percival and the early founders till 1835. He was born at Troquair Manse, Dumfriesshire, on March 14th, 1767. One of his brothers was British Minister at the Court of Berlin. Peter Ewart became a partner with Mr. Oldknow, of Stockport, the original fabricator of muslins in this country. He read a paper before the Society on "The Measure of Moving Force," in which he discusses whether, according to some authorities, the measure of moving force was the mass multiplied simply by the velocity or, according to others, by the square of the velocity.

Sir William Fairbairn, Bart., F.R.S., is the best known of the engineers who have adorned this Society. He was born at

Kelso, in Roxburghshire, 1789. Elected to this Society 1824. He was imperfectly educated in his youth. His father was a farm bailiff. Fairbairn worked at various mechanical places in England, and finally settled in Manchester, without either capital or connections, in 1817. He published papers on the strengths of materials, which were of great value, and constructed along with Robert Stephenson, assisted by the calculating genius of Eaton Hodgkinson, F.R.S., the celebrated Britannia and Conway tubular bridges. Fairbairn was President of this Society from 1855 till 1860. He died at Moor Park, Surrey, 18th August, 1874, aged 85 years.

Eaton Hodgkinson, F.R.S., was born at Anderton, near Northwich, Cheshire, 26th February, 1789, and died 18th June, 1861, aged 72. He was elected a member of this Society 1820, and acted as President from 1848 till 1851. He was Professor of the Mechanical Principles of Engineering in University College, London. His scientific labours consisted chiefly in making several long and elaborate series of experiments on the strength of materials used in construction, chiefly timber and iron.

John Frederick Bateman, F.R.S., son-in-law of Sir William Fairbairn, was elected 1840. He was engineer to some of the greatest waterworks in the world, that of Manchester, to which the water is brought from Woodhead, and that of Glasgow, to which the supply comes from Loch Katrine. In 1881 he was engaged on the Thirlmere scheme.

Sir John Hawkshaw, another eminent water engineer, elected 1839, was still a member of the Society in 1881, when he left Manchester.

William Sturgeon, the celebrated electrician, born at Whittington, Lancaster, in 1783, spent his time from 1838 till his death (8th December, 1850) in close relations with this Society. He was elected a member in 1844. To keep his father—a clever man, but an idle shoemaker—poaching fish and rearing gamecocks, when starving the family, was the painful work of young Sturgeon. He quitted shoemaking to enlist in the Westmoreland Militia, afterwards served twenty years in the Royal Artillery, and subsequently obtained the appointment of Teacher of Natural Philosophy in the East India Company's Military College in Addiscombe. Whilst serving in the Artillery his attention was awakened and his curiosity quickened by the phenomena of a terriffic thunderstorm, and this set him to the study of electricity. He began the study of Mathematics, Latin and Greek, and French, German, and Italian, which he read with considerable facility. No man contributed a greater

number of isolated discoveries of equal value and importance, or left behind him a greater number of instruments for others to work with. He contributed fifty papers to this Society.

He was Superintendent of the Victoria Gallery of Practical Science. This was discontinued owing to the pressure of the times, and he was deprived of any means of subsistence. After struggling with difficulties which would have weighed most men down, he was at length, through the intercession of Mr. Binney, another member of the Society, and other friends, placed by Lord John Russell on the Civil List for a pension of £50 per annum. He died within two years afterwards, leaving a wife and daughter unprovided for. Thus wretchedly did the Government at that time value the scientific achievements of such men of genius who did so much for the material welfare of the country.

Mr. Sturgeon, it is said, was above the average height; "his open brow and upright carriage conveyed the impression of integrity of character, an impression which was deepened by personal acquaintance."

In 1845 the Society appointed a Committee of its Members: John Thom (of Chorley), James Young, F.R.S. (of Paraffin Oil fame), and John Moore, the then President, to report on the potato disease which was at that time prevalent. They found that treatment of the potatoes in bulk with the fumes of burning sulphur was the most effective preventive.

Joseph Chesborough Dyer, V.-P. of this Society, elected 1818, was born in Connecticut, U.S.A., 17th November, 1780, and died at Manchester, 3rd May, 1871, aged 92. He claimed to be an English subject, as the date of his birth preceded the War of Independence. He was in New London during its bombardment and burning by the English Fleet under the command of Benedict Arnold. He and his men protested against the bombardment of an open town, but they had to obey the higher command. Boarded, when at school, with Mr. Sands, a watchmaker, he became enamoured of mechanics. As a boy, his father took him to Wickford, U.S.A., to enjoy boating and fishing. Here he constructed an unsinkable lifeboat. He invented fur-shearing and nail-making machinery. In 1825 he, with Darnforth, invented the roving frame; in 1811 the carding engine. At this time he was in communication with Robert Fulton, the inventor of the successful steamboat in America. The miserable event known as the "Peterloo Massacre" roused him to the abuses of the time.

In 1830 he, with others, took the contributions of Man-

chester to Paris for the relief of the wounded in the Revolution of July of that year, and to congratulate Louis Philippe on his election to the throne, and as Chairman of the Reform League, he arranged public meetings in large towns in favour of the British Government recognising Louis Philippe, which influenced it in rejecting the overtures of Russia and Prussia to make a joint war to restore Charles X. In 1832 he established machine-making works at Gamaches, Somme, France. These were destroyed in the revolution, by which he lost £126,000.

He established the Bank of Manchester, which ended in disaster, and thereby he lost £96,000. He aided in the establishment of the Manchester Royal Institution and the Manchester Mechanics' Institute.

In conjunction with Edwin Baxter, John Shuttleworth, J. B. Smith, M.P., and others, Mr. Dyer took the first step for founding a newspaper in Manchester to support the cause of enlightened Liberalism. The *Manchester Guardian* was the result, the management, literary and commercial, being intrusted to John Edward Taylor and Jeremiah Garnett. He was also active in founding the Manchester, Liverpool, and District Bank, which, falling into better hands, was more fortunate than the Bank of Manchester In 1839 Mr. Dyer built Moldeth Hall (now used as a home for incurables).

Richard Roberts, elected 1823, was a constant attendant at the Council Meetings of the Society for many years. He was born at Carreghova, in North Wales, 1789, died in London, 1864, aged 75 years. He had exhausted his funds in constant experiments, and died a poor man. As a youth he worked in mines and stone quarries and dragged canal boats. Accident gave him an opportunity of working with a pole lathe, and he made for his mother a spinning wheel, a feat so remarkable for a boy who never was at school, that a subscription was got up for him to give him a tool chest. He became a member of the great firm of Sharp, Roberts, and Co., and during his life produced 300 inventions, the best known being the self-acting mule. He invented the slide lathe, the slotting machine with automatic motion, and the planing machine. He constructed the blockade runner "Flora," and other vessels, and at one time made turret clocks.

He was consulted by Napoleon III. about turret ships, and the Emperor Nicholas invited him to take up his residence in St. Petersburg.

Dr. James Prescott Joule, F.R.S., elected a member of the

Society 1842, followed Fairbairn as President during 1860 and 1861. He was again elected during 1868-9, 1872-3, and 1878-9. He was born at Salford, 24th December, 1818; educated by private tuition. At the age of sixteen he became the pupil of Dalton in Chemistry and Natural Philosophy. Between 1837 and 1854 he attended closely to the business of his father's brewery, his leisure being spent in scientific research.

In 1843 he was engaged in the study of the effect of heat on gases, which proved that the relation between work and heat is definite and invariable, which he termed "The Mechanical Equivalent of Heat." From 1843 to 1849 he continued to work to determine the equivalent with precision, and finally ascertained that one unit of heat, *i.e.*, the heat required to raise one pound of water through 1° Fahr., was capable, when converted into work, of raising 772 lbs. through a distance of one foot. It has been named "Joule's Equivalent," and is unquestionably the most important constant quantity in Molecular Physics, and has furnished the basis of calculation for all mechanical energy.

Dr. Edward Schunck, F.R.S., was born in Manchester 1820; elected 1842; President, 1878-9. Acted as Secretary from 1855 till 1860. He did much work in connection with colours, and gave valuable contributions as regards the green colouring matter of plants. He demonstrated that the coal tar base, Anthracene, was chemically closely allied to the Alizarine of the Madder root, and pointed out that it should be possible to convert the one into the other. Twenty years later, Graebe and Liebermann in Germany, and W. H. Perkin in England, achieved the result by different processes, the patent by the former being taken out twenty-four hours before the latter in England. He died at Kersal on 13th January, 1903, aged 83.

Edward William Binney, F.R.S., F.G.S., elected 1842, became President 1862-3, again during 1876-7, and, lastly, 1880, till his death in the following year. He was born at Morton, in Nottinghamshire, in 1812, and died 19th December, 1881, aged 69. He did much valuable geological work, and was associated with Dr. James Young, F.R.S., in the development of the Paraffin Oil Industry in Scotland. He contributed 146 papers to the Society. He conceived the idea of enlarging the Society's House in George Street, but died before it was carried out. Nothing was done until the year 1883, and during this and the following two years about £2,000 was raised by subscription, handsome donations having been given by Dr. Henry Wilde, Sir Henry E. Roscoe, Dr. James Young, F.R.S. (of Glasgow), Dr. Ludwig Mond, F.R.S., Mr. H. D. Pochin, Dr. William Charles Henry, Dr. Angus Smith, Mr. Charles J. Heywood,

Mr. Andrew Knowles, Dr. Schunck, and others. The improvements consisted in the building of libraries and other rooms over the first-floor rooms and making extensions and improvements at the back and front of the building. Finally, we are indebted to the generosity of one of our most illustrious members—Dr. Henry Wilde, F.R.S., for an endowment of £8,265, the interest of which is at present employed for the purposes of the Society.

Dr. Robert Angus Smith, F.R.S., elected 1845, was President of the Society 1864-5. He was born at Glasgow, 15th February, 1817, and died at Manchester, 1884, at the age of 67. He was the first chief inspector under the Alkali Act, which became, under his judicious administration, a great success. He was much interested in the impurities of the Manchester atmosphere. He wrote in 1881 "A Centenary of Science in Manchester," in the preface of which he says: ". . . The Literary and Philosophical Society has made Manchester a scientific centre for a whole century, and has done much to dispose it to seek a University and given it a right to demand one—a right which has been conceded."

He further remarks à propos of his appeal to the public for a fund for extending the building of the Society's rooms:—

"Manchester is rich, but without science it will not remain so." There are about eighty copies of this work left in the Society's possession. It is an exceedingly interesting volume, some of the members, or others, may desire to possess a copy: such can be obtained through the Secretary.

William Crawford Williamson, LL.D., F.R.S., elected 1851, was President 1884-5. He was born at Scarborough, 24th November, 1816, and died at 43, Elms Road, Clapham, 23rd June, 1895, aged 79 years. Professor of Botany at the Owens College.

His first paper to the Society was given in 1836, on "The Distribution of Organic Remains in the Oolitic Formations on the Coast of Yorkshire."

Between that date and 1895 he contributed seventy-one papers to the Society, chiefly on Palæontology, the most important being in connection with the fossil-fauna and flora of the coal measures.

Joseph Baxendell, F.R.S., F.R.A.S., elected 1858, the Astronomer, of Southport, was Joint Secretary for many years, from 1861 to 1873 with Professor Dr. Henry E. Roscoe, and from 1874 till 1880 with Professor Osborne Reynolds, M.A.,

F.R.S. He was born at Bank Top, Manchester, 19th April, 1815; died at Southport, 7th October, 1887, aged 72.

The Right Hon Sir Henry E. Roscoe, P.C., B.A., LL.D., F.R.S., etc., Professor of Chemistry at the Owens College, elected 1858, became President 1882-3. He was born in 1833 at London; died 18th December, 1915, aged 82. He did much valuable chemical work, amongst which may be mentioned Spectroscopic Analysis, which he studied under Bunsen. He discovered the true atomic weight of Vanadium.

Osborne Reynolds, LL.D., M.A., F.R.S., M.Inst.C.E., Professor of Engineering at the Owens College, Manchester, elected 1869, President 1888-9, was one of the Hon. Secretaries for many years. Born at Belfast, 23rd August, 1842; died at Watchet, Somerset, 21st February, 1912, aged 70.

He contributed sixty-three Memoirs to the Society, chiefly on physical phenomena, such as "Various forms of Vortex Motion," "The Shattering of a post struck by lightning," etc. He showed an interesting experiment suggested by the sand on the sea shore becoming excessively wet when standing on it. He filled an indiarubber bag with wet sand, to which was attached a tube, and showed that when the bag was squeezed the water rushed into it through the tube from a glass vessel, and when the pressure was removed the water rushed out.

Dr. Henry Wilde, F.R.S., was elected 1859. He has made important discoveries and inventions in the region of electricity, and has propounded a theory in which he compares the infinitely minute ions, of which the atoms of elements are composed, to the sun and planets. The relative figures which he has calculated between the motions and weights of the infinitely large, as compared with those which constitute the infinitely small, are very remarkable, and have certainly opened a great field for future thought and speculation, which may in the future result in the discovery of another great law, like those with which we associate the names of Dalton and Joule.

Dr. Angus Smith has published a very important paper, which, taken with that of Dr. Wilde's, may lead to important results in connection with the atomic theory. It refers to the relative absorbing power of charcoal for various elementary and compound gases. Thus he found that charcoal absorbs eight times the volume of oxygen which it does of hydrogen, and as the specific gravity of oxygen is sixteen times greater than hydrogen, it absorbs 16 x 8, or 128 times the weight of hydrogen. With carbon-dioxide it absorbs 22·05 volumes, or half the molecular weight number in volumes. Here we have

fields for new and epoch-making discoveries, and I trust that in the years to come the Society will be as fruitful in such, as it has been in the past.

At present there are about 150 members, and it would be very satisfactory at the present time, when science and scientific investigations have become recognised to a much greater degree than heretofore, that we should induce some of our leading manufacturers and merchants to support this Society by becoming members, and so aid in sustaining the vigour of the long and illustrious career of this historic institution.

In this brief sketch of the progress of the Society, which I have contrived to give within an hour, I have reluctantly found it necessary to leave out the names of many eminent men who were members, who have passed away, as well as of those who are still members with us, and who have so greatly helped to uphold the prestige of the Manchester Literary and Philosophical Society.

I. The Specification of Stress. Part V.

By R. F. Gwyther, M.A.

(Received and read May 8th, 1917.)

On the Formal Solution of the Elastic Stress Equations.

There is little gained by introducing the bodily forces, which will be supposed to be conservative. It is also intended that "resistances to acceleration" should be included among "forces" in cases of motion and these will be different in different problems. I shall therefore leave the forces to be supplied as required; in other words, I omit "particular integrals," and deal with "complimentary functions" only. Solutions will only be of real interest when they are shown to satisfy the surface traction conditions of a special problem, but the knowledge of a general formal solution may lead to the solution of particular cases, and in any case the possibility of such a proceeding is necessary to my argument.

The set of equations with which I propose to deal are:

$$\nabla^2 P + \frac{2m}{3m-n}\frac{\delta^2}{\delta x^2}(P+Q+R) = 0,$$

with two similar equations,

$$\nabla^2 S + \frac{2m}{3m-n}\frac{\delta^2}{\delta y \delta z}(P+Q+R) = 0,$$

with two similar equations . . . . . (1),

and $$\nabla^2 (P+Q+R) = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

We therefore have, in the first instance,

$$P + \frac{m}{3m-n}\, x\frac{\delta}{\delta x}(P+Q+R) = \Theta,$$

$$Q + \frac{m}{3m-n}\, y\frac{\delta}{\delta y}(P+Q+R) = \Phi,$$

$$R + \frac{m}{3m-n}\, z\frac{\delta}{\delta z}(P+Q+R) = \Psi,$$

$$S + \frac{m}{2(3m-n)}\left\{ y\frac{\delta}{\delta z} + z\frac{\delta}{\delta y}\right\}(P+Q+R) = \Theta',$$

$$T + \frac{m}{2(3m-n)}\left\{ z\frac{\delta}{\delta x} + x\frac{\delta}{\delta z}\right\}(P+Q+R) = \Phi',$$

$$U+\frac{m}{2(3m-n)}\left\{x\frac{\delta}{\delta y}+y\frac{\delta}{\delta x}\right\}(P+Q+R)=\Psi',$$

where $\nabla^2\Theta=0$, &c., $\nabla^2\Theta'=0$, &c . . . . . (3).

From these we deduce

$$P+Q+R+\frac{m}{3m-n}\left\{x\frac{\delta}{\delta x}+y\frac{\delta}{\delta y}+z\frac{\delta}{\delta z}\right\}(P+Q+R)$$
$$=\Theta+\Phi+\Psi \quad . \quad . \quad . \quad . \quad (4).$$

I shall suppose that all the functions are arranged in homogeneous groups, and shall proceed with the homogeneous groups of order r.

We shall then have

$$((r+3)m-n)(P+Q+R)_r=(3m-n)(\Theta+\Phi+\Psi)_r \quad . \quad (5),$$

and

$$P_r=\Theta_r-\frac{m}{(r+3)m-n}x\frac{\delta}{\delta x}(\Theta+\Phi+\Psi)_r,$$

$$Q_r=\Phi_r-\frac{m}{(r+3)m-n}y\frac{\delta}{\delta z}(\Theta+\Phi+\Psi))_r,$$

$$R_r=\Psi_r-\frac{m}{(r+3)m-n}z\frac{\delta}{\delta z}(\Theta+\Phi+\Psi)_r,$$

$$S_r=\Theta'_r-\frac{m}{2((r+3m)-n)}\left(y\frac{\delta}{\delta z}+z\frac{\delta}{\delta y}\right)(\Theta+\Phi+\Psi)_r,$$

$$T_r=\Phi'_r-\frac{m}{2((r+3)m-n)}\left(z\frac{\delta}{\delta x}+x\frac{\delta}{\delta z}\right)(\Theta+\Phi+\Psi)_r,$$

$$U_r=\Psi'_r-\frac{m}{2((r+3)m-n)}\left(x\frac{\delta}{\delta y}+y\frac{\delta}{\delta x}\right)(\Theta+\Phi+\Psi)_r. \quad (6).$$

The components of the force per unit volume in the directions of the axes are found on simplification to become

$$\frac{\delta\Theta_r}{\delta x}+\frac{\delta\Psi'_r}{\delta y}+\frac{\delta\Phi'_r}{\delta z}-\frac{(r+3)m}{2((r+3)m-n)}\frac{\delta}{\delta x}(\Theta+\Phi+\Psi)_r,$$

$$\frac{\delta\Phi_r}{\delta y}+\frac{\delta\Psi'_r}{\delta x}+\frac{\delta\Theta'_r}{\delta z}-\frac{(r+3)m}{2((r+3)m-n)}\frac{\delta}{\delta y}(\Theta+\Phi+\Psi)_r,$$

$$\frac{\delta\Psi_r}{\delta z}+\frac{\delta\Theta'_r}{\delta y}+\frac{\delta\Phi'_r}{\delta x}-\frac{(r+3)m}{2((r+3)m-n)}\frac{\delta}{\delta z}(\Theta+\Phi+\Psi)_r,$$

and equated to the proper expression for the particular term in the expression for the force these give the relations between the arbitrary functions. We may take

$$\Theta'=\frac{\delta^2\lambda}{\delta y\delta z},\quad \Phi'=\frac{\delta^2\mu}{\delta z\delta x},\quad \Psi'=\frac{\delta^2\nu}{\delta x\delta y},$$

where λ, μ, ν, are arbitrary spherical harmonic functions, and then express Θ, Φ, Ψ in terms of λ, μ and ν on the lines of Airy's solution.

A Theory of the Displacements of the Material Bodies as a Consequence of Stress.

In this final portion of the paper I hope to be able to explain the proposal I wish to put forward of a method of treating questions of the stress and displacement in an elastic body. It has been with the object of justifying a method of this kind that I have written the several parts of the paper, but the details of the scheme and its practical application have developed themselves in the course of the work, and it would have been better if this latter portion had been ready first.

To explain my proposals, I shall commence with the remark which is, I think, obvious: That a material body can only be free from stress between its component particles when each such particle is moving freely under such system of forces as the particles are subject to; and that this is the case whether the body be rigid or yielding.

If a beam is at rest, supported in any mode under gravity, the material of the beam is in a state of stress, and if the beam is swinging about an axis under gravity, the material is in a state of stress, which in this case varies not only with the position of the particle considered, but also with the time.

My proposal is intended to be applicable to cases of motion as well as to cases of rest. We are to deal first with the hypothesis of rigidity, and accordingly I shall assume that questions of the Statics and Dynamics of the rigid body do not enter into the present enquiry. In fact, I shall proceed not only as if such questions were solvable, but as if they had been actually solved.

We will treat the number of elements of a stress as six, and not nine, and this is undoubtedly the case in the material stresses of a rigid body. But if the stress is definite, and as the number of conditions from which it can be deduced are only three in number, we are entitled to assume that there is some condition generally affecting the elements of a material stress. Any such hypothesis must be reasonable, and must find justification both on mathematical and physical grounds. The condition which I shall assume is: That the elements of a material stress are functions of the first differential co-efficients of some vector. The physical justification of this hypothesis lies in the superstructure of analysis of stress and strain which has been developed out of Hooke's Law, and the general acceptance of the doctrine by engineers and physicists. The mathematical justification is put forward below. (Appendix A.)

On this hypothesis it has been shown in Part IV. that six equations are to be found, giving at any rate to a first approximation the six elements of stress, and in the earlier parts of this paper it is shown in general terms how they are to be solved.

No complete solution of any special case is given, and the surface traction conditions have not been considered at all. I may, however, say that we are in possession of the equations from which the stresses in a rigid body, whether in a definite state of motion, or in a definite position of equilibrium, are to be found.

The next step is to introduce Hooke's Law, which I shall for the purpose of this paper state as follows:—

In an elastic body the vector, of the first differential coefficients of which the elements of the stress at a point are functions, is the displacement of that point.

Accordingly the elements of stress having been found, we are to determine the displacement from $a=S/n$; $b=T/n$: $c=U/n$.

If the body is in motion, the displacement will be a function of the time as well as of the point, and we may deduce the velocity and acceleration of the displacement. Whether the body is at rest or in motion, we may proceed to consider the displaced or strained condition of the body, and to deduce corrections for the stresses, and thence again for the displacement, if such procedure were desirable.

The method of procedure here indicated appears to conform with methods which have proved useful in other fields, and by deferring the notion of a displaced position until the first measure of the stress has been made, and by doing away with the idea of a "natural" state of the body in which it is free from stress, the tendency is in the direction of simplification. The whole change may be described as consisting (1) of introducing a general condition as affecting all stresses as preliminary to introducing Hooke's Law, instead of making it appear to be a consequence of Hooke's Law, and (2) of making the stress equations fundamental instead of putting the displacement equations in that position.

APPENDIX A.

On General Stress-strain Relations.

In the latter part of this series I have pointed out that, in as much as the displacement is eliminated in forming the stress equations, these equations apply to stresses which have the general character of elastic stresses, although they may not satisfy the specific requirements. In this section I propose to examine the results of a hypothesis that the nine elements of a stress may be functions of the nine first differential coefficients of the components of some vector.

The method I shall employ is one that I have already made use of in a paper read before the Society,[1] to which I venture to refer the reader.

[1] *Manchester Memoirs*, Vol. ix. (1895), No. 3.

Briefly, I shall find the results consequent on an infinitesimal rotation, components ω_1, ω_2, ω_3, of the axes about their own positions upon the elements of stress, and upon the first differential coefficients of an arbitrary vector of components u, v, w.

In each case I shall indicate by $\Omega_1, \Omega_2, \Omega_3$, the coefficients of ω_1, ω_2, ω_3, in the resulting expression of change in any of the elements, so that $\Omega_1, \Omega_2, \Omega_3$ will be differential operators acting on an element.

In the case of the elements of stress, the form of these operators depends on the laws of resolution of these elements. In the case of the first differential coefficients of the components of the vector, the form depends on the laws of differentiation. In one case the argument may be described as mechanical, in the other case as geometrical.

I shall replace the nine actual differential coefficients by the letters $e, f, g; a, b, c; \xi, \eta, \zeta$, by which we are accustomed to indicate the elements of strain and the components of rotation. They may be regarded as virtual elements of strain, etc.

For the present purpose, the interest lies in the operators and their employment, rather than in the mode of obtaining them.

In the case of the element of stress.

$$\Omega_1 = 2S\left(\frac{\delta}{\delta Q} - \frac{\delta}{\delta R}\right) + (R - Q)\frac{\delta}{\delta S} - U\frac{\delta}{\delta T} + T\frac{\delta}{\delta U} + \Psi_3\frac{\delta}{\delta \Psi_2} - \Psi_2\frac{\delta}{\delta \Psi_3}.$$

In the case of the first differential coefficients.

$$\Omega_1 = a\left(\frac{\delta}{\delta f} - \frac{\delta}{\delta g}\right) + 2(g - f)\frac{\delta}{\delta a} - c\frac{\delta}{\delta b} + b\frac{\delta}{\delta c} + \zeta\frac{\delta}{\delta \eta} - \eta\frac{\delta}{\delta \zeta},$$

and the values of Ω_2 and Ω_3 can be written down by symmetry.

The similarity of these expressions is well marked, and would become more so if we write e' for $2e$, f' for $2f$, g' for $2g$.

According to our hypothesis, the elements of stress are to be functions of the first differential coefficients, and thence, for example, both P and Ψ_1 are to be solutions of $\Omega_1 X = 0$, and their general values are to be obtained from the eight independent solutions of

$$\frac{de}{o} = \frac{df}{a} = \frac{dg}{-a} = \frac{da}{2(g-f)} = \frac{db}{-c} = \frac{dc}{b} = \frac{d\xi}{o} = \frac{d\eta}{\zeta} = \frac{d\zeta}{-\eta}.$$

These general values having been found, values of other elements may be deduced by cyclic interchange. The discrimination between terms in P and in Ψ_1 may be made to depend on such relations as

$$\Omega_2 P = -2T, \qquad \Omega_2 \Psi_1 = -\Psi_3,$$

by which also the elements R, S, T, may be found.

If we limit ourselves to the case when the elements of stress are linear functions of the first differential coefficients, we shall obtain the elastic stress-strain relations, with the addition of

$$\Psi_1 = k\xi, \qquad \Psi_2 = k\eta, \qquad \Psi_3 = k\zeta.$$

I do not propose to complete the general solution nor to deal with invariant and covariant functions generally, nor with the application to fibrous or crystalline bodies by the employment of constants related to determinate directions in the body, and on that account affected by the operators $\Omega_1, \Omega_2, \Omega_3$.

Instead of dealing with the general solution of the differential equations containing higher powers of the differential coefficients, I shall take only one case, that put forward by Lord Kelvin, dealing with the quadric in the natural state of a material which becomes a sphere in the strained state.

According to the method of this section the left-hand side of the equation to this quadric should be a covariant expression. Writing the expression as

$$Ex^2 + Fy^2 + Gz^2 + 2Ayz + 2Bzx + 2Cxy,$$

the conditions of covariancy as affecting the coefficients are seen to be that

$$\Omega_1 = 2A\left(\frac{\delta}{\delta F} - \frac{\delta}{\delta G}\right) + (G - F)\frac{\delta}{\delta A} - C\frac{\delta}{\delta B} + B\frac{\delta}{\delta C},$$

with two similar expressions.

From the formation of the equation of the quadric from expressions such as

$$h' = \left(1 + \frac{\delta u}{\delta x}\right)h + \frac{\delta u}{\delta y}k + \frac{\delta u}{\delta z}l,$$

we find

$$E^* = 2e + e^2 + \tfrac{1}{4}(b^2 + c^2) - (b\eta - c\zeta) + \eta^2 + \zeta^2,$$
etc.

$$A^* = a + \tfrac{1}{4}bc + \tfrac{1}{2}a(f + g) + (g - f)\xi + \tfrac{1}{2}(c\eta - b\zeta) - \eta\zeta,$$
etc.

and we can verify that the condition of covariancy is satisfied.

Now we can form expressions for the elements of stress to the second degree in the first differential coefficients, which will also conform with the geometrical conditions in the Theory of Elasticity, by writing

$$P = \tfrac{1}{2}(m - n)(E + F + G) + nE,$$
etc.,

$$S = nA,$$
etc.

*These expressions are, algebraically, partly of the first order and partly of the second order, but in estimating them arithmetically it is to be noted that ξ, η, ζ, are not necessarily small and may be large.

It is usual to require that the stresses Ψ_1, Ψ_2, Ψ_3 are non-existent; it should, however, be pointed out that if all nine of the elements of stress are existent, we may either express the elements of stress in terms of first differential coefficients, or *vice-versâ*. but if the Ψ-stresses are nonexistent, the methods are not reversible. We can express the remaining six elements of stress in terms of the nine differential coefficients, but cannot express the nine different coefficients in terms of the six elements of stress.

There appears to be two cases to mention. Firstly, that in which we omit all reference to the rotations ξ, η, ζ, as well as to the stresses Ψ_1, Ψ_2, Ψ_3. This would lead to a simplification, but would find no justification, either on physical or geometrical grounds. The second remark is that if we confine ourselves to terms of the first order of differential coefficients, Lamé's statement of the elastic force takes the form

$$(m+n)\frac{\delta}{\delta x}\left(\frac{\delta u}{\delta x}+\frac{\delta v}{\delta y}+\frac{\delta w}{\delta z}\right)-2n\left(\frac{\delta \zeta}{\delta y}-\frac{\delta \eta}{\delta z}\right)$$

etc.

and that the inclusion of a force due to the elastic Ψ-stress, would not alter the form of the expressions, although it would affect the determination of the values of the constants.

It is also worth while to note that no reasons are given for excluding the Ψ-portions of the stresses from the tractions which can be applied to the surface of the body under consideration. The grounds for omitting these portions of the stresses are that the body would be unable to sustain the elemental couple which would act throughout the body as a mathematical consequence of such stress components. In other words, that fracture would result or in some way the ordinary mathematical methods would become inapplicable.

APPENDIX B.

On the Formation of the Fundamental Equations.

If we follow Newton's statement of the Laws of Motion, the formation of the equations fall into two parts—the estimate of the forces causing a rate of change of momentum, and the expression in proper terms of the corresponding rate of change of momentum.

In the case of changes of internal momentum, due to tractions exerted on the surface of a portion of a material body, we need to make preliminary assumptions:—that the ordinary mathematical processes, such as those of differentiation and integration apply to the problems, and also that the conditions applicable to special theorems, such as Green's Transformation, may be freely made use of. The

Transformation from surface integrals to volume integrals, which is the basis of the theorem connected with Green's name, may be looked upon as the mathematical correlative to Faraday's conception of a Field of Force, and I propose to make use of the Transformation in that sense in the paragraphs which follow. I shall regard the "body" as made up of particles which are possessed of a molecular structure, in consequence of which the particle may be supposed to possess an internal angular momentum, which we may figure to be of a gyrostatic type, and that this angular momentum is capable of variation by a suitable couple. I shall also suppose that a closed surface can be drawn in the body, which can move so that no mass is carried across this surface, either from within outward, or from the outside inwards. I shall assume that the ordinary processes of mathematics, and the conditions for the employment of Green's Transformation apply to the case.

Taking l, m, n as the direction-cosines of a normal to the surface measured outwards, and using $\int dS$ and $\int dV$ to denote integration over the closed surface, and over the included volume respectively, we shall have relations such as:

I. The rate of change of momentum in the direction of the axis of x of the matter within the surface

$$= \int (Pl + Um + Tn - \Psi_3 m + \Psi_2 n) dS$$

$$= \int \left(\frac{\delta P}{\delta x} + \frac{\delta U}{\delta y} + \frac{\delta T}{\delta z} - \frac{\delta \Psi_3}{\delta y} + \frac{\delta \Phi_2}{\delta z} \right) dV.$$

II. The rate of change of angular momentum about the axis of x

= the moment of the rate of change of linear momentum about the axis of x

$$+ \int \Psi_1 dV.$$

The usual method of supposing the surface to be indefinitely contracted only serves to hide the fact that an assumption has to be made at this stage. I propose to formulate an assumption that the body is made up of particles as already described, and that the particles are in a field of stress, the elements of stress at any particle being a function of the coordinates of that particle, and that the force acting on that particle is the force resulting from such a distribution or field of stress.

On this assumption we replace I. and II. by

I. The rate of change of the momentum of the particle of coordinates x, y, z, in the direction of the axis of x

$$= \frac{\delta P}{\delta x} + \frac{\delta U}{\delta y} + \frac{\delta T}{\delta z} - \frac{\delta \Psi_3}{\delta y} + \frac{\delta \Psi_2}{\delta z},$$

and

II. The particle possesses an internal angular momentum, of which the rate of change about the axis of $x = \Psi_1$.

The Ψ-elements of stress will no doubt generally be null, but I have retained them, as it is possible that they may play a part in a theory of fracture or of permanent set.

The question of the mathematical expressions for the momentum and rate of change of momentum of the particle depends upon the amount and character of the degree of freedom which the particle is to enjoy.

If the particle is to be unrestrained in its freedom to move, and is only influenced by the forces arising from the field of stress in which it finds itself, we may suppose that the position of the particle at any time is a function of the three quantities which determined its position at some epoch, and of the time elapsed since that epoch. If we take the mass of the particle to be invariable, the expression for the rate of change of momentum is known. Under this head comes the case of fluid motion, and the propagation of a small disturbance, but not any case of molar motion in which any finite portion of the material suffers a change of position approximately comparable with a rigid motion of that portion.

Passing to the other extreme, we may take axes in motion such that the origin has the velocity u_o, v_o, w_o and the axes have angular velocities $\omega_x, \omega_y, \omega_z$ about their own positions in space. If then the velocity of each particle in the directions of the lines in space occupied by the axes is given by

$$u_o - \omega_z y + \omega_y z$$
$$v_o - \omega_x z + \omega_z x$$
$$w_o - \omega_y x + \omega_x y$$

where $u_o \ldots \omega_x \ldots$ are functions of t only, we can deduce the rate of change of the particle's momentum. On integration over the whole of a body we might deduce the whole of Rigid Dynamics. In the motion of a rigid body the parts of the body are subject to stresses, which are not elastic stresses; these stresses have no Ψ-element, and they are no doubt quite definite, but they are not defined by the rates of change of momentum of the constituent particles. Between the two extreme cases we have mentioned, there exists a wide range of

possible cases, but the conditions with which I propose to deal approximate in general character, though not in detail, to the case of rest and motion of a rigid body, and my object is to consider the points of difference.

I shall therefore assume that the components of the velocity of a particle may be written

$$U = u_o - \omega_z y + \omega_y z + u\,,$$

$$V = v_o - \omega_x z + \omega_z x + v\,,$$

$$W = w_o - \omega_y x + \omega_x y + w\,,$$

where x, y, z are the coordinates of a particle, that u_o, v_o, w_o; ω_x, ω_y, ω_z are functions of t only, and that u, v, w are functions of x, y, z, and t.

We shall have

$$\frac{\delta U}{\delta x} = \frac{\delta u}{\delta x}, \text{ etc. ;}$$

$$\frac{\delta W}{\delta y} + \frac{\delta V}{\delta z} = \frac{\delta w}{\delta y} + \frac{\delta v}{\delta z}, \text{ etc. ;}$$

and

$$\frac{\delta W}{\delta y} - \frac{\delta V}{\delta z} = 2\omega_x + \frac{\delta w}{\delta y} - \frac{\delta v}{\delta z}, \text{ etc. ;}$$

and it will be assumed that the spacedifferential coefficients of u, v, w are small.

Then on differentiation we shall find that the rate of change in U

$$= \frac{\delta U}{\delta t} + \frac{\delta U}{\delta x} U + \frac{\delta U}{\delta y} V + \frac{\delta U}{\delta z} W,$$

in and similarly for the rates change of V and W. Each of these expressions consist of three parts;

1. A part independent of u, v, w.
2. A part containing elements from u, v, w, and ω_x, ω_y, ω_z.
3. A part containing elements from u, v, w only.

If the particles of a body are either constrained to move or restrained from free motion, they are subject to some force, and are in a state of stress. This is the case when a beam is supported so as to prevent freedom of each particle of the beam to fall under gravity, as well as in cases of motion, even when the material is supposed to be rigid. We may suppose the number of elements of the stress to be six, and that we have not enough conditions drawn from the laws of motion to determine these elements.

If we suppose that the elements of stress are such functions of an arbitrary vector as I have proposed, we reduce the number of arbitrary elements to three. I am now able to sketch an outline of my proposal of dealing with questions of material stresses.

Consider the case of a body in motion. I shall first regard the body as rigid, and suppose that the problem is solved on that basis, and that $u_o, v_o, w_o, \omega_x, \omega_y, \omega_z$ are determined.

Then consider such equations as

$$m(\dot{u}_o - v_o w_z + w_o \omega_y - \dot{\omega}_z y + \dot{\omega}_y z)$$
$$- (\omega_y^2 + \omega_z^2)x + \omega_x \omega_y y + \omega_x \omega_z z)$$
$$= \frac{\delta P}{\delta x} + \frac{\delta U}{\delta y} + \frac{\delta T}{\delta z}.$$

These equations are to be treated as the statical stress equations have been treated, the reversed effective forces being included as " forces," and the corresponding values of the elements of stress determined as above.

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II. Natural and Artificial Parthenogenesis in Animals.

By D. Ward Cutler, M.A. (Cantab)

Assistant Lecturer and Demonstrator in Zoology in the Victoria University of Manchester.

Parthenogenesis, the production of an organism from an egg which has not been previously fertilised by the male element or caused to develop by artificial means, is of common occurrence in the animal kingdom, though, as will be seen, confined to but few of its great divisions.

This phenomenon has been long known, but until recently was not regarded as of much importance in relation to general biological problems. The cytological discoveries and the work that has been done on the problem of the cause of sex has, however, brought into prominence the importance of parthenogenesis.

In 1906, a paper on the cytological aspect of parthenogenesis in Insects was published by Hewitt in the *Memoirs*, of this Society, in which he reviewed the principal work that had been done up to that time. Since then the number of publications have increased enormously, and some of the conclusions recorded in Hewitt's paper have proved to be erroneous. I feel, therefore, that it may be of use to bring together some of the most important results which have been obtained by recent workers, and to indicate their bearing upon a few general biological problems. Passing in review the principal divisions of the animal kingdom in which parthenogenesis is known to occur, it is found that the Arthropoda afford by far the most numerous examples. Among the Crustacea, most of the Cladocera and very many of the Ostracoda are capable of producing parthenogenetic eggs, and in almost all the groups of Insects some examples can be found. Outside the Arthropoda many of the Nematoda habitually reproduce by this method and in other invertebrate groups a few cases can be cited.

In order, however, to obtain a clear understanding of much that follows in the paper it is necessary to realise that the sex of the animal produced by parthenogenesis is not always the same, and that the interpolation of this method of reproduction causes complicated life cycles to occur.

LIFE HISTORIES AND PARTHENOGENESIS.

Cladocera.—In the Spring females are produced from eggs that have remained dormant during the Winter. These lay parthenogenetic eggs through the Summer from which other females hatch, so that a large number of generations are produced. As Autumn approaches, however, males appear parthenogenetically, which fertilise the females. The fertilised eggs are larger and have a thicker coat than the Summer eggs. These so-called Winter eggs remain dormant during the cold months and give rise to females the following Spring.

The life history of the Ostracoda is similar to the above except that in some species parthenogenesis may continue almost indefinitely.

Rotifera.—A cycle, analogous to that already described, occurs here. In Hydatina senta the Winter egg gives rise to a female which lays eggs parthenogenetically. From these females hatch which reproduce in the same way; at certain times, however, a second type of female occurs capable of producing two kinds of eggs. If males are present fertilisation takes place and a Winter egg is produced. If males are not present, eggs are laid from which males appear parthenogenetically.

Aphidæ.—Here again the majority of the species pass through the Winter as resting eggs, produced in the Autumn by a female which has been fertilised. From these resting eggs females are hatched, the stem mothers, which lay large numbers of eggs developing parthenogenetically into other females. The stem mothers are wingless, as are also, in many species, the first few generations of females which hatch from the eggs she has laid. At certain seasons, however, winged migrants are produced which pass to other plants. Toward the end of the year these migrant females lay parthenogenetic eggs from which wingless males and sexual females appear. Fertilisation takes place and the resting Winter egg produced. Slight modifications of this generalised account occur, as for example among the Chermes, the aphids living on conifers, but the main outlines are preserved in all the species.

Cynipidæ.—In the examples already given one common character is the production of many parthenogenetic generations before the sexual forms are produced.

A more simple life history is to be found among some of the Hymenoptera, as in the Cynipidæ or gall-fly family. Here, in many species, there is a regular alternation of generations. Sometimes the galls produced by one generation are entirely different from one another in appearance, as are also the insects producing them; this occurs in Neuroterus lenticularis, whose life

history I will briefly describe, and which has been extensively worked upon by Doncaster.

In the Spring, from a fertilised Winter egg parthenogenetic females arise and lay their eggs in oak buds. From these eggs males and females, the sexual generation, appear in the Summer. Copulation takes place and the fertilised female lays her eggs in the tissue of young oak leaves. From these eggs the asexual generation will appear in the following Spring.

The life cycle summarised above does not, however, appear in all the species of Cynipidæ. In Rhodites rosæ, for instance, parthenogenesis appears to continue almost indefinitely as the number of males produced is remarkably few. This condition of things is also found in some of the Phasmidæ, and many of the Nematoda.

Bees and Wasps.—As is well known, the eggs which are fertilised give rise to the queens and workers, that is to females, for the workers are but females imperfectly developed, while the unfertilised or parthenogenetic eggs usually give rise to males; a few authentic cases are known, however, where workers have laid eggs not fertilised, from which females have hatched.

Tenthredinidæ (Sawflies).—Here we get the same female producing parthenogenetic eggs and those which require fertilisation. In some species from the former kind males are produced, in others females; while some sawflies are entirely bisexual.

Lepidoptera.—These insects offer many examples of parthenogenesis which may be called accidental. In the silkworm (Bombyx mori) and in Lymantria dispar two or three consecutive generations have been obtained without fertilisation occurring, males and females being produced from the virgin eggs. Moreover, in the Psychidæ parthenogenesis is a normal phenomenon resulting in female offspring.

Summarising what has been given above, we can divide parthenogenesis into three groups.

1. Accidental, where the normal mode of reproduction is the sexual one: parthenogenesis only occasionally taking place, *e.g.*, Bombyx mori.

2. Facultative, where the same egg may or may not be fertilised, *e.g.*, ants, bees and wasps.

3. Obligative, where the eggs are not capable of being fertilised because of the absence of males, *e.g.*, Aphids, Cladocera, etc. It is of great interest to note at this stage that in all the cases mentioned fertilisation produces a female, but the parthenogenetic eggs may produce males or females.

EXTERNAL FACTORS AS THE CAUSE OF PARTHENOGENESIS

A great deal of work has been done in trying to ascertain whether or not the external conditions play the largest part in causing the change from the parthenogenetic mode of reproduction to that of the sexual one. Kurz in 1874 showed that if the water in which Daphnia were living was slowly evaporated sexual forms appeared, and it was suggested that the increased concentration of the salts was responsible for the change. In 1905 a paper appeared by Issakowitsch, showing that starvation and low temperature were wholly responsible for the changed mode of reproduction. The view that external conditions were not the sole agents in the production of this change was advocated by Weissman in 1875. His conclusion was that the animals were so constituted by natural selection that they tend spontaneously to reproduce sexually in the appropriate season; and that they so do to a large degree irrespective of the external conditions. Thus, according to this observer, the change from parthenogenesis to sexual reproduction is an inherited character. A more recent worker takes an intermediate view; thus, according to Papanicolau, the external and internal conditions act together in the production of males and sexual females. He recognises three periods:

1. Purely parthenogenetic period comprising the first few generations.

2. Transition period, when warmth induces parthenogenesis and cold sexual reproduction.

3. Late period, when the females are sexual and no external conditions can cause them to become parthenogenetic.

Agar, however, does not entirely agree with the above conclusions. From work done on Simocephalus vetulus, he says that there is no justification for stating that sexual forms appear after a certain number of generations have elapsed since the last fertilised egg; and that the onset of sexuality is influenced by environmental factors. It has long been known that among the Aphids during the Summer months reproduction is entirely parthenogenetic, and it was generally assumed that the cold of the later months caused the appearance of sexual forms. Kyber in 1851 experimented on the rose aphid (Aphis rosæ). By keeping the animals in a warm chamber he was able to extend the parthenogenetic cycle for four years. Identical results were also obtained by Slingerland in 1893. Comparatively little experimental work has been done in this group, but it is clear that external agents do have some influence on the life cycle of some species of Aphids.

In Hydatina senta there are two kinds of females, those which parthenogenetically produce other females with a similar method of reproduction, and females which produce males in the same way. These females are also capable of being fertilised. The problem is to discover what are the factors concerned with the appearance of these various forms.

Maupas connected the variation with differences in temperature, and Nussbaum with variations in nutrition, but the results they obtained were not very conclusive. Punnett worked on a strain which had proved to be entirely female producing and subjected it to temperature variations. The rate of reproduction was reduced, but no male-producing females developed. The same result was obtained by feeding experiments. He therefore concluded that temperature and nutrition have no effect on male production and that it is the property of certain females to produce male-producing females in a definite ratio; and also that the differences between the females were due to variations in the character of the gametes which united to form the resting egg from which each strain sprang.

Recently extensive experiments have been made by two American zoologists, Whitney and Shull. Shull in 1910 came to the conclusion that neither temperature nor starvation had any effect, but that the chemical content of the water in which the animals lived was the decisive agent in the production of males.

A solution of horse manure was sufficient entirely to prevent the appearance of males, and identical results were obtained after the solution had been boiled or dried and redissolved. The substance in the solution which effected the result was found also to be insoluble in ether or absolute alcohol.

The alkalinity of the water was also tested. A solution of $\frac{N}{10}$ NaOH was diluted with ten times its own volume of spring water, which was slightly alkaline: a second solution of the same substance was also diluted with forty times its own volume. The result of the experiment, controls being used the whole time, was that the greater the alkalinity the fewer males were produced. This lowering in the number of males was also observed with a weak solution of urea.

Solutions of ammonium chloride, ammonium nitrate, and ammonium hydroxide in the strength of $\frac{M}{500}$, all caused the proportion of males to be reduced to one half the normal number.

A further paper was published by Shull and Ladoff in 1916, in which it was shown that oxygen in the water increased male production.

At about the same time Whitney was working at this problem with five species of Rotifers: Hydatina senta, Brachionus pala, Diaschiza iterea, Diglena catellena, and Pedalion mirium. If the parthenogenetic females of Hydatina senta, Diaschiza iterea, and Diglena catellena are fed on a Polytoma diet female-producing daughters are exclusively developed; if these females are, however, transferred to a diet of Chlamydomonas they produced 80 per cent. or more male-producing daughters. A scanty diet of green flagellates favoured the production of female-producing females in the other two species of Rotifers, while a superabundance of the same diet caused high male production.

From these experiments the conclusion was drawn that the change of diet was the external agent for the production of males and females. However, as Shull has remarked, the increase in the production of males when the diet was a Chlamydomonas one may be explained by the increased oxygen which is produced by photosynthesis; this assumption is also borne out by the experiments of feeding scantily or abundantly with cultures of green flagellates. This explanation is, however, not entirely satisfactory, for when green algæ, which were too large to be eaten, but which would produce oxygen, were put into the water in which the animals were living, the result was negative. Thus it is probable that nutrition has some effect, but to what extent is not definitely ascertained.

Internal Factors as Operative Agents.

As already mentioned, Punnett came to the conclusion that the whole problem could be solved on the basis of heredity, and that internal agents and not external ones were the operative factors. This conclusion was tested by Shull. Two pure lines were obtained, one from Baltimore, the other from New York; the external conditions were as far as possible rigorously kept constant. From the former the proportion of males hatched was 11·1 per cent., from the latter 18·5 per cent., and these proportions were found to be constant. Males and females from the two pure lines were crossed, and the resulting lines had in every case a higher proportion of male-producing females. On crossing one of these hybrids back with either of the original parents, the offspring gave rise to pure lines with a proportion of males intermediate between those of the two parent lines. Further, it was shown that with long-continued parthenogenesis the percentage of male production was reduced. Punnett's conclusion was not, however, entirely justified, for it was possible to alter the constant ratio of male-producing females by changing the external conditions. Thus the F_1 generation, which yielded more male-producing females than its parents, was caused to produce

less by placing the animals in beef extract, which had previously been shown to act as a deterrent to male production.

A very interesting result of the experiments was the demonstration that there are definite male and female-producing females, and that the same female does not give rise to both male and female-producing daughters. Whether a female is to be a male-producer or a female-producer is decided during the growth period of the parthenogenetic egg from which it is hatched. Thus "sex is determined a generation in advance." It appears evident that both external and internal agents are at work in the change from parthenogenesis to sexual reproduction. These internal agents are probably capable of causing the appearance of males without any outside aid; indeed the evidence goes to prove that when external agents, with few exceptions, operate male production is prevented or diminished.

It is possible that some external stimulus may modify the normal course of events in the internal economy of the egg. The discovery that oxygen increases male-production indicates that the cause may be attributed to an increased speed of reaction in the protoplasm. There is evidence also that the chromosome number is different in the two types of egg, and that the method of maturation is also different. It is possible therefore that the external agents may so act on the egg as to cause the appearance of one or other mode of maturation, also, as we shall see later, there is evidence that in the Aphids the external and internal factors act together in the production of males and sexual females.

Cytological Aspect.

As is well known, during the maturation divisions of the germ calls of sexual female and male animals, the somatic number of chromosomes is reduced to one half; and thus when fertilisation occurs the somatic number is again obtained.

From the researches of numerous cytologists during recent years it has been demonstrated, that in some species the males produce two kinds of spermatozoa, which differ one from the other in the number of chromosomes, one type possessing one or more than the other. The eggs are all alike in having an equal number. These chromosomes are also in many cases characterised by differing in shape and size from the others, and are known as X-chromosomes or sex chromosomes. Thus if 2n represents the somatic chromosome number, omitting the sex ones, the female will possess $2n + 2X$, and the male $2n + X$. After maturation divisions all the ova will have $n + X$ chromosomes, while the sperms will be of two types:

(1) $n + X$ chromosomes;
(2) n chromosomes.

Sperms of the second type fertilising an ovum will produce males, while those of the first type will form females.

In passing, it is worth mentioning that from the inheritance of sex limited characters there is reason to think that in a few animals, Lepidoptera and Birds, the reverse is the case and the female has two kinds of eggs. Cytological investigation has largely confirmed this view.

In light of these facts it is of considerable importance to discover what occurs in the maturation of parthenogenetic eggs.

The question as to whether the chromosomes are reduced in number at the maturation divisions of the parthenogenetic egg is full of interest, and, as will be seen, in those eggs in which reduction does occur, modifications have developed to ensure that the normal number is reformed in subsequent generations.

Ostracoda and Cladocera.—The parthenogenetic eggs of the Ostracoda have only one maturation division, which is equational, so that the number of chromosomes is not reduced.

Weissmann, in 1886, showed that the parthenogenetic eggs of Polyphemus produced only a single polar body and that the chromosome number was not altered. Kuhn investigated the parthenogenetic eggs of Daphnia pulex and Polyphemus pediculus and arrived at the same conclusions. The cytological aspect of male production in these forms has not been investigated.

Branchiopoda.—Von Brauer (1893) as a result of research on Artemia salina announced that there were two types of parthenogenesis occurring in the same animal. In the first and most common the chromosome number was not reduced and only one polar body was formed. In the second type, however, both polar bodies were developed, and during the formation of the second the chromosome number was halved. This second polar body, however, instead of passing to the exterior of the egg and degenerating remained in the egg and gave rise to a reticular nucleus, which fused with the female pronucleus. Thus there was fertilisation by the second polar body.

Petrunkewitsch (1902) reinvestigated the subject, but was unable to find any trace of the second type of parthenogenesis. He therefore concluded that it was due to a pathological condition and was not a natural one. This was in the main the conclusion of Fries (1909).

Finally, in 1911 and 1912, two papers appeared by Artom in which it was stated that there were two races of Artemia, a parthenogenetic one and a sexual. The former differs from the latter in possessing a double number of chromosomes. The parthenogenetic race (Artemia bivalens) develops with the diploid

number of chromosomes, while the eggs of the sexual race (Artemia univalens) maturate in the usual manner.

It thus appears highly improbable that Brauer's account is correct.

Ants, Bees, Wasps.—Petrunkewitsch (1901) studied the maturation divisions of the unfertilised eggs which give rise to the male Honey bee, and showed that two polar bodies are produced, the first division being the reductive one. He further asserted that after the production of the polar bodies the inner half of the first polar nucleus fused with the second polar nucleus to form a single one. The female pronucleus migrated inwards and the outer half of the first polar body degenerated. The nucleus formed by the fusion of portions of the polar bodies gave rise to the male germ cells by subsequent divisions.

The number of chromosomes in the original nucleus before maturation was sixteen, after the formation of the polar bodies each nucleus had eight chromosomes, and the original number was reformed in the male germ cells by the fusion of the products of maturation. As the somatic cells are developed from the female pronucleus, which contained only eight chromosomes, the normal number, sixteen, was produced by a further division of the chromosomes, which on this occasion did not separate from one another.

This somewhat fantastic hypothesis was not disputed until 1904, when Meves published a short note, followed by more detailed work in 1907.

Meves attacked the problem by studying the maturation of the germ cells of the male bee. He first showed that the number of chromosomes in the queen bee is thirty-two, and not sixteen, as Petrunkewitsch supposed. The spermatogonial cells of the male contain sixteen chromosomes, that is, half the normal number. At the first maturation division the chromosomes appear as eight long double rods, which shorten and thicken; the result of division is not two cells, each with eight chromosomes, but one large cell containing eight double chromosomes and a small enucleate bud at the top of the spermatocyte.

At the second division the chromosomes divide equationally, but instead of forming two functional cells, which will develop into spermatids, only one functional cell with eight double chromosomes is produced and the other cell degenerates. Thus, as a result of maturation, only one spermatozoa instead of four is developed from each spermatogonium.

In 1908 Meves published the result of investigations on the Hornet. Here the first spermatocyte division is similar to that of the bee, but the second division, on the other hand, results

in the production of two daughter cells, each of which develops into a spermatozoa, and each containing the reduced number of chromosomes.

In these insects therefore we have the peculiar feature that the male passes the whole of its existence with half the normal number of chromosomes in the germ cells. The difficulty of how such an animal can at fertilisation restore the normal number to the egg is overcome by the suppression of the reductive division in the maturation of the male germ cells. In the somatic cells the chromosomes may divide to form 32 or 64.

Nachtsheim (1913) reinvestigated the whole subject with great care, and has in the main confirmed the conclusions arrived at by Meves. In both fertilised and parthenogenetic eggs the maturation divisions are the same. The innermost group of the first polar body fuses with the second polar body to form the "richtungskopulationkern;" while the outermost part of the first polar body degenerates. This "richtungskopulationkern" is formed in all eggs, but it soon degenerates and gives rise to no part of the insect, as Petrunkewitsch asserted.

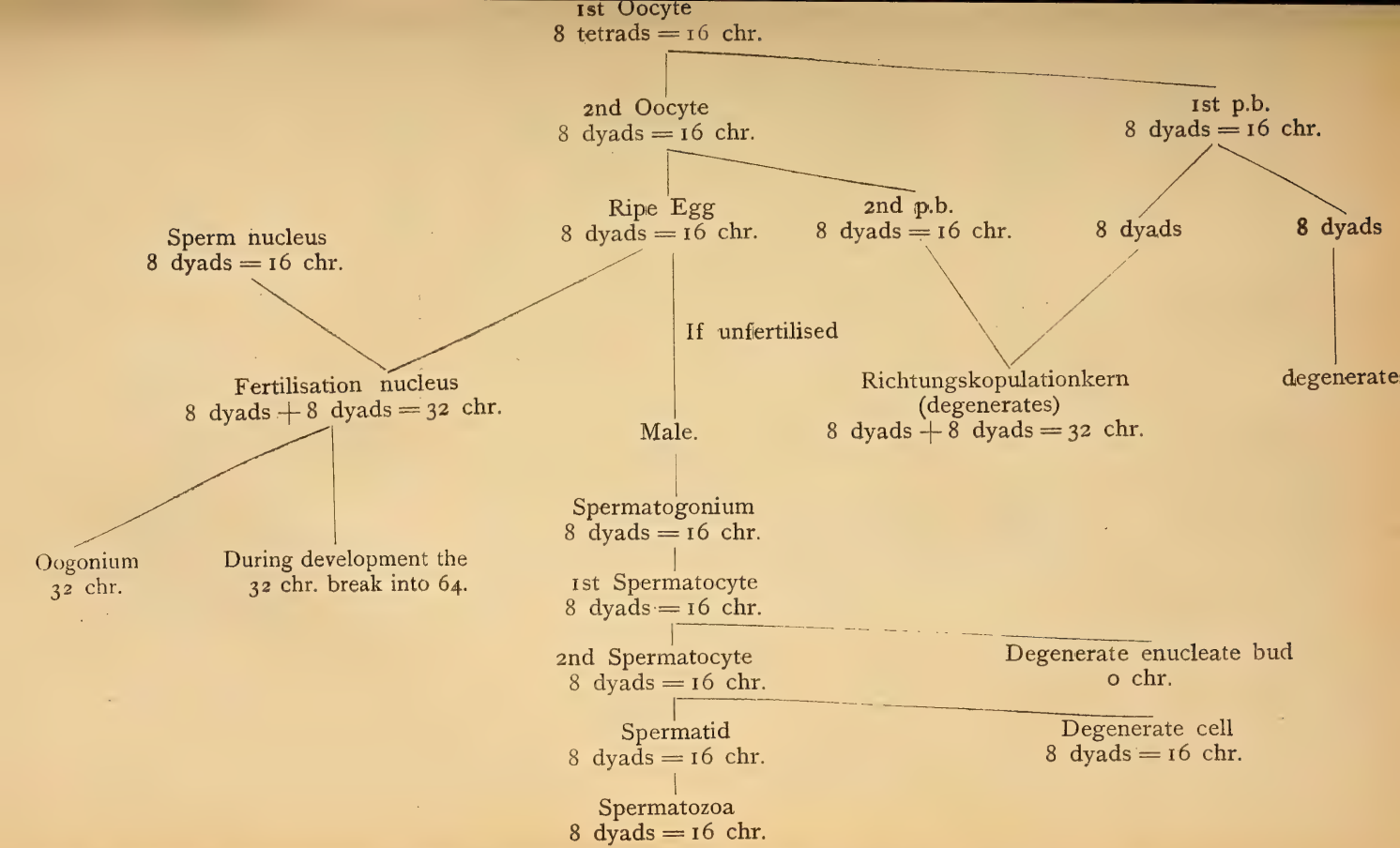
The whole process is rendered clear by reference to the table, which is modified from the one given by Nachtsheim. (Diagram A.)

Exactly comparable results have been obtained by other observers in Osmia cornuta, Xylocopa violarea, and in a few species of ants.

The question as to the way in which the sexes are produced on the basis of sex chromosomes is also discussed by this author. He assumes that of the female chromosomes thirty are somatic and two sex chromosomes ($30 + 2X$). At maturation reduction occurs, giving a nuclead complex $15 + X$, thus the unfertilised egg will develop into a male. During spermatogenesis no reduction takes place and all the chromosomes divide, so that all the spermatozoa possess $15 + X$ chromosomes; thus fertilisation will always result in the production of females.

Rotifera.—The maturation of the parthenogenetic eggs of Hydatina senta is similar, as regards male formation, to that described above. According to Whitney, the parthenogenetic eggs which will give rise to females have only one maturation division, and thus only one polar body is produced and the chromosome number is not halved. In the eggs which will give rise to males, however, the two polar bodies are formed and the chromosomes reduced; this also occurs in the maturation of the winter egg.

We are, unfortunately, ignorant of the spermatogenesis of Hydatina, and therefore do not know whether the sperms are all alike or whether there are two classes produced, one forming



Scheme of life cycle of Honey bee (modified from Nachtsheim).

on fertilisation, eggs from which female-producing females hatch, the other male-producing females.

Aphidæ.—This group of insects has been worked upon a great deal by American cytologists. Morgan has investigated with much care the Phylloxera and a fairly complete account of the life history from a cytological standpoint is known.

In P. fallax there is a single stem mother which lays parthenogenetic eggs, and from these develop wingless female insects. These females produce large eggs from which sexual females appear, and small eggs producing males. Fertilisation occurs, and from the eggs laid the stem mother of the following Spring hatches.

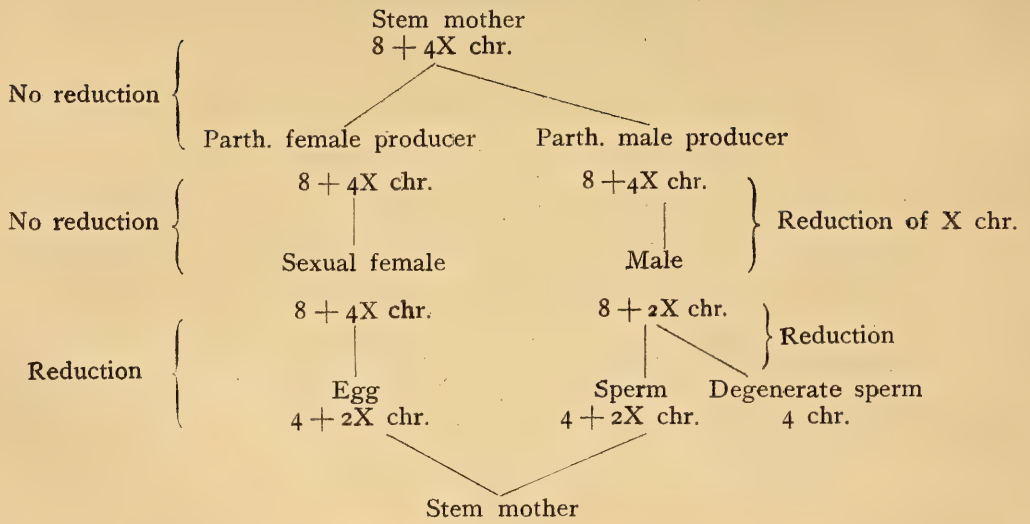
The stem mother has twelve chromosomes, four of which are sex ones. The parthenogenetic eggs which this female lays also differ in their mode of maturation. From the sexual female-producing eggs one polar body is extruded and there is no reduction in chromosomes; the male-producing eggs also form one polar body, but the four sex chromosomes pair and two pass into the polar body to be thrust out of the egg, leaving ten chromosomes ($8 + 2X$) in the female pronucleus. The males thus possess ten chromosomes and the sexual females twelve ($8 + 4X$). At spermatogenesis the eight somatic chromosomes pair and four pass to each pole of the spindle, the 2X chromosomes also pair but do not separate, and both pass to one pole. In this way two classes of spermatids are produced, one with six chromosomes ($4 + 2X$), the other with four; this latter degenerates, so that all spermatozoa contain six chromosomes.

The maturation of the eggs of the sexual females is of the normal type, so that when fertilisation takes place the original chromosome number is restored to the egg, which gives rise to the next stem mother. (Diagram B.)

A second species, P. caryæcaulis, is of interest because it has been demonstrated that there are two types of stem mothers; one kind which produces nothing but sexual females, and the other from whose eggs only males develop.

In this species there are eight chromosomes, including four sex ones. The general scheme of the chromosome cycle in the several generations is like that for P. fallax; there are, however, slight differences in the sex chromosomes, two of them being large and two small. In the males also the two small chromosomes slightly differ one from the other. Adopting Morgan's notation, we may designate the large chromosomes by X and the small ones by x; the differences in the male being denoted by priming one of the x's.

DIAGRAM B.



Scheme of life cycle of Phylloxera fallax.

At the maturation of the eggs, which will give rise to the male, the two large chromosomes pair, as do also the small ones. It will be seen from the accompanying Diagram C, that two types of males will be produced giving ries to two kinds of spermatozoa, one containing Xx, the other Xx′. If the former fertilises the eggs the resulting stem mother will be a female-producer (XXxx), if the latter, there will be formed a male-producing stem mother (XXxx′).

At about the same date Morgan investigated the Aphid of the Bearberry. This insect, Phyllaphis corveni Cockerelli forms galls on the leaves of the plant, and in each gall there is a single stem mother and her progeny. There are males and sexual females together with females which are parthenogenetic. The eggs of these latter all contain six chromosomes. The spermatogenesis of the male is very similar to that of the Phylloxera, but the spermatogonial cells only contain five chromosomes. Of these five chromosomes four pair together at synapsis, so that three chromatin clumps are formed, two of which are composed of paired somatic chromosomes, the third being the unpaired sex chromosome. At spermatogenesis the somatic chromosomes separate, but the sex chromosome passes undivided to one pole of the spindle. Thus two cells are formed, one with three chromosomes, the other with two: this latter degenerates.

Von Baehr and Stevens as the result of work done on Aphis soliceti and seven other species confirmed the above result.

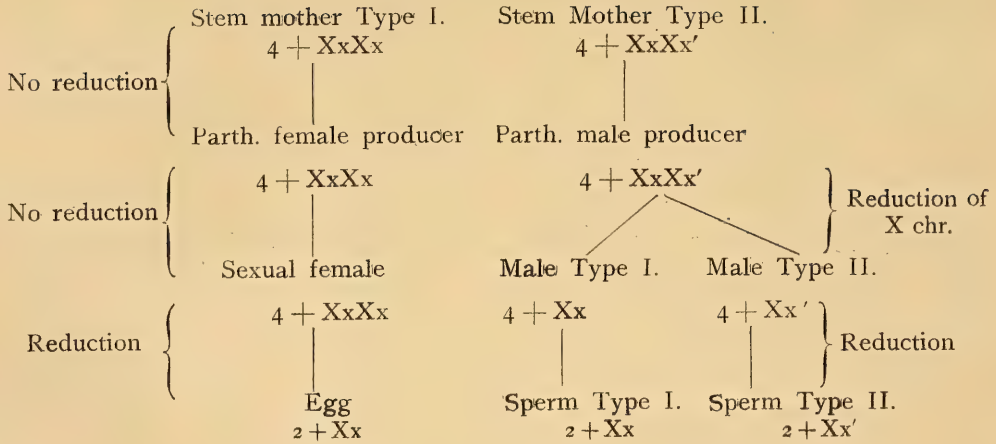
It seems to be clear that in the Phylloxeræ and Aphidæ the loss of one or more chromosomes from the egg is intimately connected with male production. That the absence of the sex chromosome is not the ultimate cause of male production is obvious, since it is determined in some way that certain eggs shall extrude the chromosomes and others not do so.

This has been noticed by Doncaster in his paper, "Chromosomes, Heredity and Sex," in which is the following sentence: "But this cannot logically be regarded as a proof that the presence or absence of X is not the cause of femaleness or maleness; it only means that some factor is present which decides whether X shall be extruded or not."

This factor may very well be environmental change, which acts on the protoplasm of the egg in a way somewhat similar to that suggested for the eggs of Hydatina senta.

Cynipidæ.—The cytology of the eggs of Neuroterus lenticularis has been worked out fully by Doncaster. As I have already mentioned, the life cycle of this insect exhibits a constant alternation of bisexual and parthenogenetic generations. In the Spring parthenogenetic females hatch from the Winter

DIAGRAM C.



Scheme of life history of Phylloxera caryæcaulis.

eggs and give rise to sexual females and males, which constitute the Summer brood. The Spring generation is also peculiar in that two kinds of females are produced, from the one kind, eggs are laid from which only males develop, from the other type only sexual females.

The somatic number of chromosomes is twenty in both the Spring and Summer generations. One of the points of interest is that the two types of females of the Spring brood differ in regard to the method of maturation of the eggs.

In the female-producing eggs no maturation divisions occur, and the chromosome number is not reduced, thus there are twenty chromosomes in the female pronucleus.

In the male-producing eggs, however, two maturation divisions take place and the chromosomes are reduced to ten.

Here then we have a condition which parallels what occurs in the formation of the drone bee.

Spermatogenesis is also similar to that of the bee. The spermatogonia contain ten chromosomes, but there is no reduction of chromosomes. The first division gives rise, as in the bee, to an enucleate bud of protoplasm and a functional spermatocyte with ten chromosomes. At the second maturation the chromosomes divide and there are formed two spermatids, each with ten chromosomes.

During oogenesis two maturation divisions take place, one of them reductive: in this way four groups of chromosomes are formed, of which the three outer form polar nuclei and the innermost, with ten chromosomes, the female pronucleus. The accompanying scheme illustrates the essential phases of the life history. (Diagram D.)

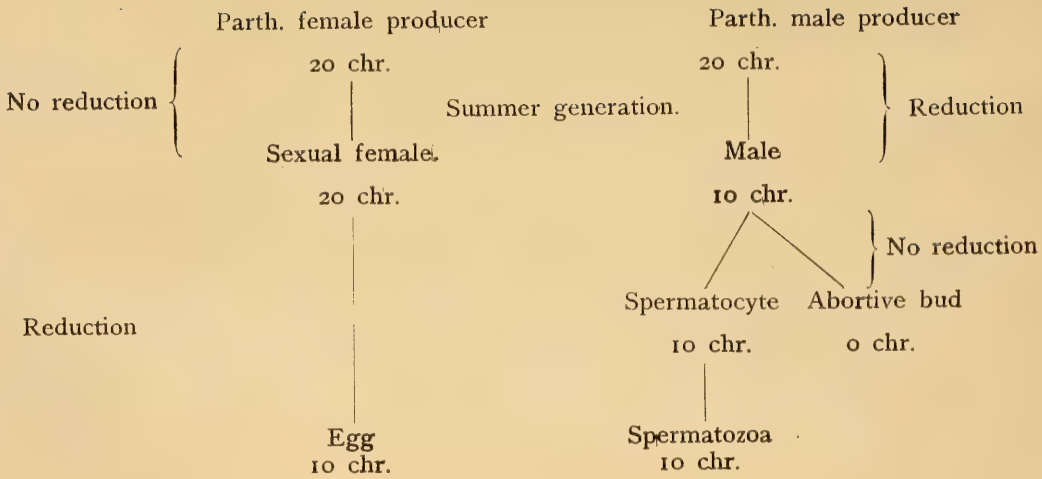
A point which still remains doubtful is what determines whether the Spring females shall be male-producing or female-producing. This was the subject of an investigation which Doncaster and I undertook. It was hoped that it might be possible to show that there were two classes of spermotozoa formed, but this expectation was not realised. At present it is impossible to indicate with certainty what constitutes the difference between these two classes of parthenogenetic females.

Rhodites rosæ.—Males are very rare in this species. In fact, Schliep, a recent worker, found none during the course of his experiments: on rare occasions, however, they are said to occur.

Henking (1892) stated that the somatic number of chromosomes was eighteen, which were reduced to nine in the eggs before maturation. The maturation division of the eggs was

Diagram D.

Spring generation.



Scheme of life history of Neuroterus lenticularis.

equational, so that though four nuclei were formed, there was no reduction of the chromosome number. He also described a fusion of the second polar nucleus with the inner half of the first polar nucleus. The outer half passed to the periphery and was extruded and fusion with the second and inner-part of the first polar nucleus occurred.

The result of greatest interest in his investigations was that the chromosomes of the female pronucleus were doubled in number before the first cleavage took place. The same phenomenon was said to occur by Petrunkewitsch in the honey bee, and by Delage in the artificial parthenogenesis of sea-urchin eggs.

Schliep reinvestigated the cytology of the egg of Rhodites rosæ. He gives the somatic number of chromosomes as ten or twelve. This number is also found in the oogonia and the oocytes, thus confirming the statement that there is no reductive division. Further, according to this observer, there is no doubling of the chromosome number after maturation has taken place, the cleavage nucleus possessing ten to twelve chromosomes.

Tenthredinidæ.—The sawflies are very varied as to the manner of reproduction; some there are which lay parthenogenetic eggs from which only males appear (Nematus ribesii); in other species parthenogenetic eggs are laid from which only females are hatched (Pœcilosoma luteolum); and a third group from which both males and females are produced from parthenogenetic eggs, as in the gallflies. Investigation into the cytological aspects were undertaken by Doncaster. As the results published for Nematus ribesii are probably incorrect, it is useless to detail them here. It is hoped that the cytology of the eggs of this insect will be re-examined at some future date, so that the present discrepancies in the account may be rectified.

In Pœcilosoma luteolum and Crœsus varus two maturation divisions occur, and the chromosomes do not appear to be reduced in number. This conclusion is probably correct, but until the spermatogenesis and oogenesis have been studied the point cannot be said to be definitely settled.

Lepidoptera.—The cases in which parthenogenesis occurs among the Lepidoptera are few. Platner and Henking studied the maturation of the unfertilised eggs of Bombyx mori. Two polar bodies were said to be formed and the chromosomes were thought to be reduced in number. Recently, however, Goldschmidt found in the Gipsy moth that the oogonia and spermatogonia of the insects, which had arisen parthenogenetically, contained the normal diploid number of chromosomes. At present our knowledge of the cytology of the unfertilised eggs of the Lepidoptera is very scanty. Goldschmidt mentions in his

paper, however, that the parthenogenetic eggs of the Psychidæ have been studied by Dr. Seiler, whose paper is in the press.

Chalcididæ.—In this group of insects we find examples of polyembryony. Silvestri studied Litomastix truncatellus; the egg gives rise to a number of cell clusters, each of which develops into a larvæ. A point of interest is that each individual which arises from the egg is of the same sex. If the original egg was fertilised females are produced, if unfertilised only males appear. Silvestri was also able to examine the maturation divisions of the ovum, and found that in both the parthenogenetic eggs and the fertilised ones they were the same. Here then we have an excellent example of sex determination by fertilisation. Further, as the maturation divisions of both kinds of eggs are of the normal order, the males will arise from eggs having the reduced number of chromosomes, and will therefore be like those of the bee and Hydatina senta.

Parthenogenesis and Sex.

If a summary is made of the preceding cytological facts it will be found that the types of maturation in parthenogenesis are two:—

(A.) One maturation division, which is not reductive, as in the Ostracoda.

(B.) Two maturation divisions:—

(1) Chromosome reduction as in the Ants, Bees, Wasps, etc.

(2) No chromosome reduction, both divisions being equational, as in Rhodites rosæ, etc.

A third type described by Brauer in Artemia we have seen to be probably incorrect.

Before proceeding to a discussion as to how the cytological study of parthenogenesis affects the problem of sex determination, it will be of advantage to enumerate the more important theories regarding sex. Castle (1903) propounded the theory that the male and female were heterozygous for sex, and that at maturation the male or female elements were eliminated with the polar bodies in the case of the female, and were segregated from one another at spermatogenesis in the male. Selective fertilisation was also assumed to occur, so that only male-producing spermatozoa could fertilise female ova, and only female-producing spermatozoa could conjugate with male ova. The zygote thus produced must of necessity be heterozogous and the resulting sex was male or female according as to which was the dominating element. There are many objections to this view, but taking one case, that of the bee, we at once encounter difficulties. As the males are produced from the unfertilised eggs which have undergone

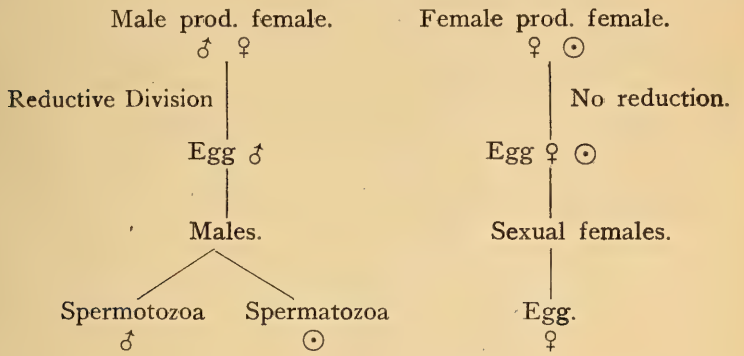
maturation and reduction, we must assume that the female element has been eliminated, but by hypothesis the spermatozoa at fertilisation must bring into the egg the female tendency. It is difficult to see how this is possible. Castle offered a solution by pointing out that the testes were developed from the fused polar bodies, and that therefore they would contain the female element. We have seen, however, that this observation of Petrunkewitsch is incorrect. A second theory due to Correns is based on experiemnts performed with Bryonia. The assumption here is that the male is heterozygous for sex, but the female homozygous. The difficulty of selective fertilisation is by this means overcome, for it is obvious that either a male or a female sperm can fertilise the ova, which in this case are all alike in character. The bee again offers difficulties, for the parthenogenetic females must bear male tendencies, but according to the theory they lack them. Beard has suggested that this can be explained by assuming two types of eggs, sexual female-producing type, which must be fertilised, and male-producing type, where the female tendency is replaced by a latent male tendency. The assumption of a latent male tendency seems to me, however, to be too speculative in nature to warrant acceptance. A reversal of Correns' formula so that the females are heterozygous and the male homozygous offers the same kind of difficulties, for, as in the Castle theory, the female tendency is eliminated at maturation of the parthenogenetic egg, and yet the sperm brings into the egg that tendency.

In the foregoing brief account of these theories of sex I have given very few objections to them, but reference to the literature of the subject will at once demonstrate that the difficulties are very numerous and are sufficiently great to warrant scepticism before they are accepted. Doncaster has formulated another view, in which it is supposed that the female is heterozygous for sex but that the male produces two kinds of spermatozoa, one of which contains a male determinant, but the other lacks any determinant for sex. The difficulty of accounting for the facts observed in the bees, etc., again arises.

Doncaster suggested that the presence of a sperm in the egg influences the maturation in such a way as to cause normal maturation to occur. Then the chromosomes are halved both quantitatively and qualitatively and the male determinant is eliminated. If the egg maturates without fertilisation the female determinant is removed. In this way the spermatocytes contain a single male determinant which passes into one spermatid, leaving the other without any determinant. This latter is the abortive bud which degenerates. All spermatozoa then contain the male determinant and after fertilisation the sperm by its presence causes the male determinant of the egg to be eliminated.

This hypothesis of sex was developed to account for the phenomena observed in the sex determination of Abraxus grossulariata and in Neuroterus lenticularis.

In Neuroterus lenticularis after spermatogenesis there would be two kinds of sperms formed, one kind possessing the male determinant ♂ the second lacking it ⊙. Thus after fertilisation there will be two types of zygote, one male-producing, ♂ ♀ the other female-producing, ♀ ⊙. At maturation the ♂ ♀ type will expel the female determinant and develop into a male, while the other, which undergoes no maturation, will produce a female.



The female determinant is transmitted to all the eggs of the sexual females of the Summer generation, because the element remains in the pronucleus of the egg at maturation.

This suggestion of Doncaster, though explaining many phenomena, is highly speculative, as he admits, and must, I think, be treated with due reserve.

The foregoing theories have all had their origin in the assumption that sex determination is a qualitative phenomenon, and that the eggs and spermatozoa carry a factor or determinant, which causes the production of either male or female.

Another theory propounded by Wilson and lately assumed by Castle presumes that sex production is brought about by a quantitative action of the germ cells. In an earlier part of the paper it was stated that in many animals the chromosome number in the male was found to be less than in the female, thus in Protenor the X element is single in the male, double in the female.

According to Wilson and Castle the determinants are not male or female respectively, but the female is quantitatively greater in some substance, probably a form of nuclear matter, than the male; thus " femaleness is due to maleness plus some-

thing else." The first objection to the hypothesis is the inheritance of certain characters in the Lepidoptera and Birds where it is necessary to assume that the order of things is reversed. As I have already mentioned ,however, there is evidence to show that in these two groups there is an odd element in the female. This is a very remarkable confirmation of the theory of the connection between chromosomes and sex, and as Doncaster remarks, "It can hardly be coincidence that the spermatozoa should be dimorphic in respect of a chromosome in the forms in which sex limited inheritance by the male takes place, and the eggs dimorphic in the same way in those in which sex limited transmission is by the female.

How then does this theory accord with the facts of parthenogenesis? In the Ants, Bees and Wasps a male is produced from eggs which have undergone reduction in the chromosome number. This is also the case with Hydatina senta, and probably so in Litomastix. Thus the female has the diploid, the male the haploid chromosome number. If, as Nachsteim suggests, in the bee, two of the chromosomes are sex chromosomes, in the female one of them is extruded at maturation and the egg will develop into a male. As all the spermatozoa of the male contains the sex chromosomes females must result from fertilisation. Whether the sex chromosomes are present or not in the female does not affect the theory, for the important point is that the male contains half the number of chromosomes found in the female.

The observations of Jack and Wheeler, showing that in rare cases workers may produce females from the unfertilised eggs, cannot be discussed until the cytology of these eggs is investigated. Three possibilities are open to account for this variation.

(A.) There may be two maturations, but both equational, as in the Saw-fly, Pœcilosoma luteolum.

(B.) There may be but one maturation division which is not reductive.

(C.) There may be non-disjunction of sex chromosomes, if these exist.

This phenomenon of non-disjunction was suggested by Bridges as the result of work on Drosophila. He found that on rare occasions the sex chromosomes of the egg stick together at the maturation divisions, and are both extruded with the polar body or both remain in the female pronucleus. If, in the case of the bee, both chromosomes remained in the female pronucleus the resulting insect would be a female.

Rhoditis and Pœcilosoma.—In both these insects females are almost invariably produced from the unfertilised eggs, and the maturation divisions are in both cases equational, which is in

accordance with the theory. The rare occurrence of males is of interest, but at present we are entirely ignorant as to whether there is any difference in the maturation of those eggs from which males are produced. It may be that the males develop as in the bee, or there may be non-disjunction where the sex chromosomes are extruded with the polar nucleus.

Lastly, the case of the Aphids must be considered. No reductive division occurs in the parthenogenetic eggs, but the males and females are hatched from them. In all cases investigated, however, the eggs from which males develop eliminate one or more chromosomes, which are retained in female-producing eggs.

Wilson has himself pointed out that in plants both males and females are formed from asexual spores, and that these spores usually contain the haploid chromosome number. This of course seems to be contrary to the theory, but it is possible that the male-producing ones may be characterised by the absence of one or more elements found in the female spores.

Goldschmidt (1917) put forward a view almost identical with the theory given above. He believes that the production of sex is a quantitative phenomenon due to two factors, one of which is carried in the sex chromosome, the other by the cytoplasm of the egg. His reasoning is practically the same as that of Wilson. The chief importance of the suggestion is the possibility that the cytoplasm may be a carrier of inherited qualities. There is much evidence for this belief, but there is also a tendency to regard the nucleus as the only factor of importance in the study of problems of heredity. This is a mistaken idea, and if the cytoplasm be excluded from all study, advance in our knowledge of the laws of heredity will be diminished.

The evidence given in a previous part of the paper is sufficient to show that the sex of an individual is affected by external conditions, but there is also reason to believe that internal factors exert a very definite influence on sex production. The probability is that these two sets of factors act together. The experiments of Geoffrey Smith are of importance in this connection. He found that as a result of parasitism by Sacculina male crabs assume the female characters and may even produce ova in the testes. Further, he demonstrated that metabolic changes occurred during the parasitism, with the result that the metabolism of the affected male became almost identical with that of the normal female. Great differences are also known to exist between the blood of male and female of the same species of many Lepidoptera. Observations such as these give rise to the suggestion that the differences between the two sexes are those of metabolism. As Doncaster says in his paper, "Chromosomes, Heredity and Sex," the general conclusion must be that although

the observations connecting a particular chromosome with the determination of one sex are in many cases indisputable; there is no evidence to show how this chromosome acts; and that since the sex of the offspring is in some cases modified by the environment, it is probable that the presence of the chromosome is associated with a particular kind of cell metabolism, of which sex is to be regarded rather as a visible expression than a cause.

Dinophilus.—I have left to the end a brief account of the mode of development of these animals, because it is so curious and unparalleled by any other organism that it is impossible at present to connect it with any scheme of sex determination.

Two kinds of eggs are laid, differing in size; from the larger one females develop and from the smaller one males. These two types of eggs are laid in the same capsule. It was formerly thought that both these eggs required to be fertilised in order to develop, but the recent work of Shearer shows that this is not the case, for the larger female-producing eggs conjugate with the sperm nucleus, while in the male-producing eggs no conjugation occurs.

In Dinophilus gyrociliatus, the species on which Shearer worked, the rudimentary males hatch from the egg in a very short time, and are sexually mature. The females, on the other hand, when they hatch are in a larval condition, and definite ova are at this stage not yet developed. In spite of this, copulation at once occurs, and the spermatozoa find their way to the place where ova will be formed. As soon as the primitive oogonial cells appear they are at once joined by the sperm which penetrates into the cells. The sperm nucleus becomes situated close to the oogonial nucleus, and when the cells divide both nuclear elements divide simultaneously. This continues for from forty to fifty divisions. Occasionally, however, the female nucleus divides first and the male nucleus is excluded from one of the daughter cells which are produced. Thus a condition is brought about in which some of the cells contain the whole of the male nucleus together with half the female nucleus, while others contain only half the female nucleus. This is the stage at which sex is determined: for those cells containing male and female elements will become female-producing eggs, while the male-producing eggs are developed from the oogonial cells containing only the female element. It will be noted that in the cells containing both male and female nuclear elements no fusion has at present taken place, and it is not until a late development of the egg that fusion of the male and female nucleus occurs.

Further, in neither the male or female eggs has there been any trace of maturation divisions. These divisions do occur,

but not until after the fusion of the male and female nucleus. Thus we have the extraordinary phenomenon of fertilisation preceding maturation. Shearer was unable to obtain a detailed account of maturation of the eggs, but there appears to be twenty somatic chromosomes in both male and female. Two polar bodies are given off by both types of eggs, and in each case twenty chromosomes are extruded and twenty remain in the egg. What occurs in the formation of the second polar body of the female egg is not known, but in the male egg ten double chromosomes are again extruded, leaving ten double ones in the egg.

As Shearer remarks, the two most remarkable results of this work are the way in which fertilisation occurs, and maturation occurring after fertilisation. The maturation divisions are also very puzzling, and cannot be satisfactorily explained. The whole difficulty is so admirably expressed by Shearer that I cannot do better than quote his own words: "With regard to maturation divisions, I am forced to admit that their evidence is very puzzling, and I am quite unable to explain them at present. In the case of the male egg, we should expect, as this has not been fertilised, and is therefore in a sense developing parthenogenetically, it should agree with the development of the male parthenogenetic egg of Rotifers, and other forms, where they develop in the "n" condition, where "n" represents the reduced number of chromosomes. This is certainly not the case in Dinophilus, where the male egg, after reduction (if any reduction takes place), possesses apparently the full 2n number. It is, however, possible that the male egg of Dinophilus is similar to that of the Phylloxerans, which develops in the 2n—1 or —2 condition, as it is difficult accurately to count the chromosomes in the segmentation divisions of the male egg on account of their small size. In the female egg we should expect them, since they have been fertilised before reduction, to be in the 2n+n condition if we consider the sperm to bring in the n number. In the first maturation division of the egg we should expect to find at least thirty chromosomes, whereas their number is somewhere about twenty. On the other hand, if we suppose the female germ cells to be in the "n" condition when they appear in the ovary, then after fertilisation they should show the 2n number of chromosomes, which agrees with the facts, but does not explain how the male egg, which has not been fertilised, is nevertheless in the 2n—1 or —2 condition. Therefore, from whatever point of view we choose to regard it, there is no way of bringing the facts of maturation divisions into line at present."*

* The question of sex production and the early differentiation, during development, of germ cells from somatic cells has been ably discussed by Hegner in a long series of papers. The whole matter is summarised in his book "The Germ-Cell Cycle in Animals." New York, 1914.

INHERITANCE IN PARTHENOGENESIS.

The inheritance of characters in parthenogenetic animals has not, up to the present, been greatly investigated. In 1899 Warren inquired into the inheritance of the ratio between the length of the protopodite of the antennæ and the body length in Daphnia magna. He found that the parental correlation was 0·466 ± 0·054 (founded on 23 parents and 96 offspring), and the grandparental one 0·27 ± 0·12 (founded on 7 grandparents and 26 offspring). This denoted that there might be a diminution of the correlation as the ancestral distance was increased, but very few individuals were investigated. Similar results were obtained by investigations made upon the Aphid, Hyalopterus trirhodus. Here the characters employed were (1) distance between the eyes; (2) the length of the right antenna; (3) the ratio of (1) and (2).

About this time Johannsen published the result of work done with Phaseolus vulgaris. Two characters were chosen for investigation, the weight of the beans and the ratio between the width and length. All the descendants arising from a single plant by self-fertilisation were called pure lines, and a number of these pure lines constituted a population. Experiment showed that in such a population the variations followed the normal curve and the correlation between the parent and offspring was 0·336 ± 0·012. When, however, pure lines were considered the variations still followed the normal curve, but the correlation between the parent and offspring was nil. Further, the deviations of the parents from the mean were not inherited.

Jennings' extensive work on Paramœcium has in a marked way confirmed these conclusions.

The recent experiments of Agar are probably the most detailed that have appeared on the subject of inheritance and parthenogenesis. He chose as his animals two species of Simocephalus, one species of Daphnia and an Aphid, Macrosiphum antherinii. In the two species of Simocephalus the character used was the body length measured at the first instar and the first adult instar, and in the species of Daphnia the ratio between the posterior spine of the carapace and the body length. The results of the investigations showed that in a monoclonal population (one known to have descended from a single ancestor) the ancestral correlation coefficients were insignificant, also there was no trace of Mendelian segregation. In general the conclusions were in complete agreement with those of Johannsen.

In the experiments with the Aphid the characters chosen were those employed by Warren. The ancestral correlation

co-efficients for the two species given below are reproduced from Agar's paper.

	Macrosiphum Antherinii.		Hyalopterus Trirhodus.	
	Parental 117 parents and 124 offspring.	Grandparental 54 grandparents and 60 offspring.	Parental 60 parents and 358 offspring.	Grandparental 30 grandparents and 291 offspring.
Antenna	0·482 ± 0 046	0·165 ± 0·085	0·427 ± 0·029	0·177 ± 0·038
Frontal Breadth	0·433 ± 0·049	0·231 ± 0·082	0·335 ± 0·031	0·321 ± 0 035
Ratio ...	0·235 ± 0·057	−0·002 ± 0·087	0·439 ± 0·028	0·230 ± 0·037

It will be seen that the two results show a certain degree of similarity, and, as Agar says, "afford a certain presumption that the co-efficients are due to the physiological relationship between the grandparent, parent, and offspring, and not the accidental results of extrinsic causes."

Reasons are, however, offered for not accepting this conclusion too readily; thus there is the possibility that the viviparous nature of the animals and their short life history may have an effect in the result; for the maternal nutrition may have influenced the size of the offspring, which was not able to attain the normal one during the short life of the insect. Further, the characters investigated were dimensional ones which are easily influenced by environment. In this connection it must also be noted that in Simocephalus exspinosus there was no evidence of any diminution of the correlation coefficients as the scale of ancestry was increased.

The many variations which occur in Aphis avernæ led Ewing to study the inheritance of some of the characters of this insect. The conditions in which the parthenogenetic females lived were kept as far as possible constant.

Pure lines were raised from these females and the mean for the characters investigated was determined in each case and found to be very constant. When extreme variants of a pure line were selected to act as parents for further lines, the mean obtained was the same as that of strains which had not been specially selected. Also the fraternal mean of a generation often exhibited great fluctuatoins from the mean of the strain, but these fluctuations were not inherited.

Finally in 1915 a paper was published by McBride and Jackson on the inheritance of colour in a stick insect, Carausius morosus. In this animal the colour patterns of the adults are

very numerous, but whatever may be the colour of the parent all the parthenogenetically produced offspring were alike in having a pattern of green and brown. It is as growth proceeds that the different colour characteristics of the adults are gradually produced. Also there was no evidence, as regards green or brown, that the colour of the mother had any influence on the proportion of the young which finally assumed these hues.

ARTIFICIAL PARTHENOGENESIS.

The second part of the paper deals with the remarkable experiments which have been performed on the eggs of various animals, not normally parthenogenetic, causing them to develop without the action of the spermatozoon. This phenomenon has been termed artificial or experimental parthenogenesis. I do not intend to give more than a very general outline of the work which has been done, as the subject is fully treated in Loeb's book, "Artificial Parthenogenesis," and also in that of Delarge and Goldsmith, " La parthénogenèse naturelle et expèrimentale." Though artificial parthenogenesis has only assumed a prominent place in biological literature during the last few years, the phenomenon was noted by a few observers much earlier.

Boursier in 1847 stated that a virgin silkworm placed in sunlight and then in shade had produced eggs from which caterpillars had developed.

Tichomoroff in 1886 published a short note on the artificial parthenogenesis in insects, in which he described how he had obtained caterpillars from a few unfertilised eggs (6 out of 99) of the silkworm by rubbing them between two pieces of cloth. This experiment is open to doubt, as later work has demonstrated that a small proportion of unfertilised eggs of the silkworm will develop without outside aid. In 1902 the same naturalist used as the stimulating agent concentrated sulphuric acid with marked success

O. Hertwig, in 1890, by shaking the eggs of Astropecten and Asterias induced the first stages of development, and in 1899 Loeb found that cleavage of unfertilised eggs of the sea urchin could be induced by the action of hypertonic sea-water. Since this date the number of workers have been exceedingly numerous and development has been induced by the most diverse means. I shall therefore content myself with giving a brief resumé of the most important theories that have been deduced from experiments, together with a short account of some of the more important experiments performed.

Theory of Loeb.

Loeb's early experiments were undertaken to discover the action of various acids on the unfertilised eggs of sea urchins. He found that cell cleavage could be induced by the action of HCl, HNO_3, H_2SO_4, etc., but after a few cleavages had occurred disintegration followed. Further development up to the plutei stage was effected in the original method by the use of a hypertonic solution of sea-water. The concentration of normal sea-water was raised 50 per cent. by the addition of sodium chloride. Unfertilised eggs were placed in this solution for two hours and then removed to normal sea-water. By further experiment it was found that practically any salt, so long as not actually poisonous, would effect the same result provided that the concentration of the water was raised 50 per cent. Thus it seemed that the stimulus for development was not due to any specific action of certain salts but to a change in the osmotic pressure.

When eggs are fertilised by a sperm there is produced round the egg a membrane, known as the fertilisation membrane, also the eggs rise to the surface of the liquid. These two results of fertilisation were not produced by the artificial method described above. This led Loeb to devise a fresh series of experiments. Eggs of Strongylocentrotus purpuratus were placed for one minute in a solution of 500 cc. of sea-water to which 3 cc. of a decinormal fatty acid had been added. The fertilisation membrane was produced, but segmentation did not occur. If, however, after being thus treated they were placed in a hypertonic solution of sea-water the eggs developed. This result was obtained with many of the monobasic fatty acids, such as formic, acetic, propionic, butyric. Summarising the results of many observations, we may say that substances causing hæmolysis also cause membrane formation, for instance, saponin, bile salts, hydrocarbons, ether, etc.

The theories that Loeb has formulated are many, but they are all purely chemical. The membrane formation was first supposed to be produced by the liquidation of fatty substances which are resident on the egg surface. As a corollary of its formation oxidations are set up in the eggs, which if allowed to continue cause disintegration, and finally the death, of the eggs so treated. These oxidations are caused because the fatty substances round the egg prevent the diffusion of OH ions, but acids and the substances favouring membrane formation dissolve the surface fats and render the egg permeable to the action of ions. The action is further supposed to consist in their combination with the albuminoid substances in the egg to form new

substances, which alter the power of the protoplasm to absorb water. This view has, however, been partially given up by the author in favour of a later one, in which it is suggested that the ions act by their electric charges causing modifications of those of the colloids.

Loeb definitely established that oxidisation is increased by membrane formation, and this oxidation, if allowed to continue, prevents development from proceeding further than a few cell cleavages. The action of the hypertonic solution, which enables development to continue to late stages, is to inhibit or alter the internal oxidations of the egg. Further, the solution must be alkaline, if neutral the egg breaks up into vesicles; also the action of the solution will only take place in the presence of free oxygen. In what way then is the development influenced? Here again Loeb's explanation is chemical. The solution causes the formation of a substance or substances which orientate the development into the right direction, or control the first phase, that is, the membrane formation phase. This is brought about by the synthesis from the protoplasm of specific nuclein substances of the nucleus, and this synthesis is again the result of an oxidation which is not of the same nature as the first one. It is necessary to note that this second oxidation is not the direct result of the hypertonic solution, but is a consequence of dehydration. Dehydration produces changes in the chemical equilibrium of the protoplasm, resulting in the dissociation of electrolytes. Loeb thus concludes that the sperm in fertilisation brings into the egg two substances:—

(1) A catalyser which causes membrane formation.

(2) A corrective substance which modifies the action of the first producing normal development.

The foregoing theories are highly ingenious, but are perhaps too speculative in character to be taken as explaining the whole process of fertilisation. Also the author is so inculcated with the chemical aspects of the problem that he is in danger of overlooking the probability that many of the phenomena may have physical explanations.

Further, as will be seen later, there are many eggs of various species of animals which do not require to be treated by the above methods; for instance, there is no need to use hypertonic sea-water in order to obtain parthenogenesis in the eggs of Polynoe, Lottia or Acmæa. These if acted upon by catalytic substances and then transferred to alkaline solutions, hypertonic or not, will readily develop.

Theory of Delarge.

Delarge was one of the first to undertake work on artificial parthenogenesis. In 1901 he tried the effect of various chloride salts on the eggs of starfish and sea urchins, and obtained development up to the blastula stage. The theory with which he is associated, however, was developed as a continuation of his views in regard to the mechanism of cell division. In 1898 Montgomery showed that it was not necessary for the male and female pronucleus to fuse in order for development to take place. Delarge extended this observation by a series of others in which he was able to get fertilisation of enucleated pieces of egg.

Cell division is, according to this observer, a series of coagulations and liquefactions of the colloidal protoplasm. This conception was then extended to account for artificial parthenogenesis. As acids are usually coagulators and alkalies liquefiers of protoplasm, Delarge treated unfertilised eggs first with HCl and then with ammonia; by this means development was induced. In later experiments tannin was employed as the coagulating substance, with much better results, for by this method development proceeded to its final stage and young sea urchins were obtained.

Later in the investigations tannate of ammonia was used with good results. This was explained by saying that the tannin was a feeble acid and the ammonia a base; when in solution separation occurred between the two substances and each worked separately.

In comparison with the work of Loeb, it is of interest that Delarge demonstrated that the presence of free oxygen was unnecessary for inducing parthenogenesis, and also that a hypertonic solution was not of vital importance.

The theory is different from Loeb's in that there is not called into play any special chemical substances. The substances necessary for development are already resident in the egg and only require to be set into motion. According to Loeb, the necessary stimulus for this is the chemical substances brought in by the sperm, according to Delarge the substances will arrange themselves in the requisite manner under the influence of molecular forces. The nuclear membrane, centrosomes, achromatic spindle and the chromosomes are transient features of the cell, appearing and disappearing in the protoplasm as though they were in a state of a sol or a gel. The agents employed for artificial parthenogenesis then act as coagulators and liquefiers, thus producing a series of coagulations and liquefactions which culminate in development. The feeble point in the theory is that these

cyclic coagulations and liquefactions, which are supposed to occur in a developing egg, have never been satisfactorily demonstrated, and until this has been done the theory must of necessity remain a speculation.

THEORY OF LILLIE.

This theory has analogies with the preceding one. Lillie maintains that in the egg there is a latent mechanism, which can be set into action by various substances. While Loeb considers that this is caused by intra-cellular oxidations set in motion by catalysers, Lillie takes up the position that the action is due to increased permeability of the egg membrane and not to any specific chemical substance. Development is always preceded by mitotic divisions of the cell, and as there is evidence that during this division there is a change in the cell permeability, Lillie concluded that this is the direct agent in artificial parthenogenesis. In 1910 he wrote: "The egg is to be regarded from a simple physico-chemical point of view as a chemically complex semi-fluid colloidal system, enclosed by a semi-permeable surface layer, the plasma membrane, which is the seat of electrical polarisation. Increase in permeability will evidently produce both chemical and physical changes in such a system; the chemical changes follow from altered conditions of interchange with the surroundings, as already seen, and involve disturbances of chemical equilibrium in the egg; these latter, on the present theory, initiate the chemical transformations which find expression in the mitotic process. The chief physical changes from the present point of view would be a decrease in the electrical potential difference normally existing between the exterior and interior of the cell. The seat of this potential difference on the membrane theory is the plasma membrane which appears to be electrically polarised in such a way as to have its outer surface constantly at a considerably higher potential than its inner; this condition, the physiological polarisation, is a function of the impermeability of the plasma membrane to ions other than certain cations, probably hydrogen ions. Here more or less complete fall of potential, *i.e.*, depolarisation, must follow an increase of surface permeability sufficient to allow ready passage of anions, such depolarisation will be accompanied by increased surface tension. Alteration of surface tension thus induced form, in all probability, an important, if not the chief factor, in the characteristic changes of cell cleavage."

This conclusion was deduced from experiments, of which the following are examples:—

Unfertilised eggs of Arbacia punctulata were found to lose their pigment when placed in isotonic solutions of various salts.

These salts, however, were not equal in regard to their power of action, thus, $Cl < Br < NO_3 < CNS < I$. This loss of pigment was taken to indicate that the surface permeability had been affected by the salts. Further, if the eggs were treated with the above solutions for varying periods, according to the salts used, and then transferred to normal sea-water development commenced and larvæ were produced. Experiments with the eggs of Asterias showed that the weakly acid salts, such as chloride and bromide, were better agents than the stronger ones. This is in direct opposition to the result obtained with Arbacia eggs, and would seem to indicate that the egg membrane of the starfish was thinner than that of the sea urchin.

As a further test whether the conception of changed permeability for inducing parthenogenesis was correct, a second series of experiments were undertaken. Calcium chloride was known to retard increase in permeability and it was therefore decided to ascertain the effect of a mixture of this substance and those that produced development.

Some eggs of Arbacia were treated as described above, while others were placed in the same solution to which small quantities of calcium or magnesium chloride were added. This latter solution prevented membrane formation and cell cleavage, while the control eggs developed into larvæ.

Fertilisation then brings about altered conditions of interchange of diffusible substances and ions; thus before fertilisation the cell membrane is only partially permeable to anions, but after fertilisation the permeability to these ions is greatly increased. The original chemical equilibrium is thus disturbed, with the result that the cell metabolism is affected in such a way as to cause development. Lyon found that during cell cleavage the production of CO_2 is not constant, but is rhythmical, the rhythm corresponding to the cleavage. This rhythm, according to Lillie, corresponds to periods of increased and decreased permeability. However, in artificial parthenogenesis the increased permeability must not be allowed to continue indefinitely, but must, after a certain period, be stopped by the use of a hypertonic solution, or some other agent producing the same effect, such as cold or lack of oxygen.

In a recent paper (1916) Gray has confirmed many of Lillie's results and demonstrated that after normal fertilisation there is a marked decrease in electrical resistance, and that for the first hour of development the resistance never returns to the same value as it had before fertilisation occurred. In a series of ex-

periments he showed that artificial parthenogenesis could be induced in the egg of Echinoids by the following methods:—

1. Eggs were treated for 1½—3 minutes with a solution of 50 cc. sea-water + 3 cc. butryic acid. The eggs were then transferred to normal sea-water for ten minutes. Following this they were placed for one hour in a hypertonic solution of sodium chloride, and then transferred to normal sea-water for development to proceed.

2. Eggs were first treated with a saponin solution and then placed in hypertonic sea-water, followed by normal sea-water.

3. Eggs were treated with strong hypertonic solutions and then with normal sea-water.

By these three methods a fall of electrical resistance was produced. McClendon had stated that this fall was dependent on the presence of an excess of alkali in the interior of the egg. This Gray found not to be the case. The resistance of the egg was also found to be markedly changed by trivalent positive or negative ions, hydrogen ions or hydroxyl ions. All these are known to polarise the membranes, and from this the conclusion was drawn that by the polarisation of the surface of the egg variation in electrical resistance was brought about leading to surface changes and altered permeability.

THEORY OF BATAILLON.

The above theories have all been developed largely from experiments upon Echinoderm eggs or those of other Invertebrates. Bataillon has for the most part confined his attention to the lower orders of the Vertebrates. Koulaguine (1898) treated Amphibian eggs with anti-diphtheric serum and induced the beginning of development. Later Bataillon confirmed this result and explained it as due to dehydration.

In his early researches the agents employed were very various and in many cases his technique was much cruder than that of his contemporary observers. Thus by pricking the unfertilised eggs of the frog he was able to produce segmentation, which proceeded up to the morula stage in the majority of cases, though three of the eggs developed into tadpoles which lived until metamorphosis.

A temperature of 40° C. followed by freezing also caused morulæ to be formed. In 1900 the effect of different hypertonic solutions were tested, but in no case did development continue

past the morula condition. Bataillon attributed these results to dehydration, which removed waste products, chiefly CO_2, which had accumulated in the resting egg. These waste products were supposed to inhibit development, which could only be initiated by their removal.

This early view was, however, soon modified to give place to a more complicated one in which there was assumed to be factors resident in the blood which act as catalysers. Further, the active agent was thought to be the nuclear matter of the leucocytes.

In order to illustrate the very varied methods that have been employed from time to time for the production of artificial parthenogenesis the following list is given, which has been modified from one tabulated by McClendon:—

1. Hypotonic solutions (distilled water).
2. Nearly istonic solutions made by adding to sea-water or to distilled water the following substances: acids, alkalies, neutral salts.
3. Hypertonic solutions made by adding acids, alkalies, neutral salts.
4. Non-electrolytes: mechanical shocks, thermal changes, fat solvents, alkaloids, blood sera, bile salts, etc.
5. Electrical shocks by induction coils.

Conclusion.

* These various agents are not effective on all species of eggs, in fact, some of the methods are only of use for one particular species. It thus appears that there are wide differences between the various kinds of eggs, and that artificial parthenogensis is not induced in the same manner for all. It is one of the problems of the future to ascertain if there is not a common factor or factors to all the methods which are capable by themselves of causing unfertilised eggs to develop. Until this is done it is practically impossible to decide what action the sperm has on the egg at fertilisation, causing it to undergo the complicated series of changes which culminate in the adult animal.

From the standpoint of the cause of sex production it is of great importance to ascertain what is the sex of the animals produced from artificial parthenogenetic eggs. These eggs have

* A summary of artificial parthenogenesis by M. Herland has recently appeared in a paper entitled "Le Mécanisme de la Parthénogenèse expèrimentale chez les Amphibiens et les Echinodermes. Bulletin Scientifique de la France, et de la Belgique. 7th Series T1, 1917.

usually undergone reduction before they are treated, and on the theory of sex chromosomes the majority of eggs with one X chromosome would develop into males. In those animals which are heterozygous for sex in the female two kinds of eggs would be formed and males and females would be expected to hatch from the eggs. Unfortunately, the facts are very few. Delarge obtained one sea urchin which he was able definitely to state to be a male, while Loeb and Bancroft reared two young frogs which they thought to be females. Recently Gatenby had published a short account of the sex of a frog raised by artificial parthenogenesis, and he is sure that it was a male. He also mentions in the paper that Loeb has announced to an American conference that an American species of frog produced by artificial parthenogenesis had proved to be a male.

A second question which is still uncertain is whether the haploid number of chromosomes is retained during the development of artificial parthenogenetic eggs. Wilson states that the reduced number is maintained in the sea urchin, but Delarge asserts that the normal number (Diploid) is restored by an auto-regulation. Hindle was able to count the number of chromosomes in the cells up to the blastula stage in Strongylocentrotus purpuratus and found the reduced number throughout.

It is stated above that artificial parthenogenetic eggs have usually undergone maturation before treatment, but a few experiments have been made on the result of treating eggs which have not formed the polar bodies. Delarge used the eggs of Asterias glacialis and found that he got the best results with eggs that had not formed the polar bodies. From this he concluded that the retention of chromatin was an important factor. Garbowski, however, with the same species of egg obtained results entirely different from those of Delarge. Finally Morris, who induced artificial parthenogenesis in Cumingia eggs by subjecting them to heat, found that normal blastulæ were developed from those eggs which had not produced their polar bodies.

These results are of interest in connection with the work of Kostanecki on Mactra, the only member of the Mollusca in which natural parthenogenesis has been studied. Here the eggs may develop and entirely omit maturation. It is premature to draw any parallel between the polar body formation in natural parthenogenesis and artificial, but there is evidence, I think, to warrant the belief that in the future some important connection may be discovered.

Meanwhile the problems of fertilisation is still far from settled. Loeb sees the chief value of the experiments in that

they appear to "transfer the problem of fertilisation from the realm of morphology into the realm of physical chemistry." This, I think, is only partially true, for though various agents have the power of calling into play the latent capacity for segmentation resident in the ovum, it does not follow that the action of the sperm is identical with that of any of these agents. Indeed, it may well be that the stimulus supplied by the sperm is peculiar to itself, and that the substances employed in the experiments produce the same effect by entirely different means. It seems to me significant that few, if any, animals have been raised to sexual maturity by these artificial means, and I would suggest that this may be accounted for by the fact that the chromatin of the male element is lacking in these cases, which have not become so modified as to develop perfectly with half the amount of nuclear matter characteristic of the species, as have a few naturally parthenogenetic eggs such as those which produce the male bees.

[While this paper has been passing through the press I have heard that Loeb has recently been able to obtain male and female frogs by artificial parthenogenesis, but whether these animals are capable of producing functional spermatozoa and ova I am not able to say.]

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III. The Organisation of Museums and Art Galleries in Manchester.

By Hon. Professor W. Boyd Dawkins, M.A., D.Sc., F.R.S.

(Read October 30th, 1917. Received for Publication November 5th, 1917.)

I. Introductory. II. Prof. Huxley and Manchester. III. The Museum Idea. IV. The Manchester Museum and its Work. V. Art in Manchester at the Present Time. VI. Organisation of Collections for New Art Gallery. VII. Museum of Technology. VIII. A New Centre of Music. IX. Conclusion.

I.—Introductory.

The place of Museums and Galleries of Art, and Technology, in our system of education is a fitting subject to bring before a Society devoted to the advancement of science and learning; and especially at this time when our eyes are opened by the War to the necessity of overhauling all the other sections of national life. The Society, itself the outcome of the intellectual movement in Manchester, in the last quarter of the eighteenth century, offered the favourable conditions under which Dalton and Joule made the discoveries that form the basis of modern chemistry and physics. It also set an example of the value of association in promoting research, that was swiftly followed, in the first half of the 19th century, by the foundation of the Natural History and Geological Societies of Manchester, for the study of nature as it is now, and as it was in the past, as well as the Royal Institution for the encouragement of Art and Literature.[1]

To the collections made by these two Societies, co-ordinated and arranged into one whole, we owe the Manchester Museum, and to the Royal Institution the gift to the Corporation of the Art Gallery site, building and collections, in Mosley Street.

[1] Nearly all the founders were members of the Society.

Also as Sir Adolphus Ward points out,[2] it was a moving force in Manchester, that contributed to the evolution of the University from its small beginnings in Owens College. It is therefore not without reason that I now lay before the Society a scheme for the further development of our Museums and Galleries that will complete our system of education by giving those who cannot attend Schools or Lectures, because of their daily work, the chance of educating themselves by the study of things, as well as of books. The keys of knowledge must be within the reach of all classes, if we are to win in the commercial struggle before us, to be decided not by brute intellect or individual courage, so much as by the organisation and the training, both of the captains, and the rank and file of industry. The victory will go to those who are best organised and are armed with the best education.

We have to make good the weak places in our armour, and among these the absence of great central public institutions for placing the highest standard of art and industry before our workers is the most pressing. We have now the opportunity of making our city as noteworthy, in the strenuous new England that will be after the war, as she was in the happy lotus-eating Victorian times, now so far behind us.

II.—PROFESSOR HUXLEY AND MANCHESTER.

Few are aware of the extent to which Manchester is indebted to Professor Huxley in the establishment and organisation of its institutions. His advice was followed in the re-organisation of Natural Science in Owens College, and he used his powerful influence in London in breaking through the obstacles and prejudices that stood in the way of the Owens College growing into a new type of University. It was in accordance with his suggestion that the Corporation took up the difficult problem of instruction in technology. I well remember that he said in a public meeting in Manchester, that he did not know the best solution, that there was not much to be learnt about it in Britain, and that Manchester was the place where the experiment should be tried—*fiat experimentum in corpore Mancuniensi*. The idea took root, and grew into the School of Technology. And lastly he took a keen interest in the organisation and development of the Manchester Museum. It was through him that I gave up, in 1869, the association with him on the staff of the Geological Survey of Great Britain, for the task of combining the various collections of Natural History in Manchester, into one living Museum. He was my unfailing refuge in times of difficulty until the completion of my task in 1884, when the collections already arranged were transferred to their present places in the galleries.

[2] *Founders' Day in War Time*, 17th March, 1917, *p.* 21.

III.—The Museum Idea.

We owe the first idea of a Museum of Science and Art in Britain to Lord Bacon (New Atlantis) and the first realisation so far as relates to science, to Elias Ashmole, who founded in 1667 the institution at Oxford bearing his name. This consisted mainly of natural history specimens, mingled with miscellaneous antiquities, now re-organised by Sir Arthur Evans, and transferred to new quarters close to the Taylor Buildings, it has grown into the most perfect classical museum in Britain. It was not until 1747 that the British Museum, which had grown round the centre offered by the Library, was recognised by Act of Parliament. The modern Museum, arranged for scientific purposes, cannot be traced further back than the middle of the 19th century, and is the outcome of the scientific renascence associated with the names of Darwin, Huxley, Flower and Rolleston. The old type of Museum, with its curiosities and other objects, intended to excite wonder, horror or disgust, survived even in Manchester until the beginning of the 'seventies, and still survives elsewhere in small country towns. It was this obsolete type that the House of Commons had in mind, in 1915, when they closed the British Museum, and other institutions in London for the duration of the War as being of little interest and of little or no value to the general public or to the large influx of visitors from our Colonies and America. Here, in strong contrast to this retrograde measure, both Museums and Art Galleries are not only kept open as before, but are being utilised for systematic instruction in the elementary and secondary schools. In this new development, as in other fields of action, Manchester has taken the lead. In dealing with the general question of Museums and Galleries in Manchester, I shall treat the Manchester Museum as a going concern, see how far it is efficient as a new type specially fitted for the local needs, and lastly how far its principles and methods can be applied to the enlargement of the existing or the founding of new public institutions for the education of the people.

IV.—The Organisation of The Manchester Museum.

The Manchester Museum administered by the University as Trustee for the public, and supported by the University and the Corporation of Manchester, is the result of the co-operation of the Natural History and Geological Societies which handed over their collections to the Owens College in 1870, in trust for the good of Manchester. It is intended for the use of students in the University, and the advancement for the study of nature among the people. Its scope was enlarged in 1912 by the addition of a new block, to include objects relating to the history and culture of mankind, and more especially of the Egyptian collections presented by Mr. Jesse Howarth.

The difficulty of grouping together the various objects telling the story of the history of the earth, from its beginning down to the

present day, in logical sequence, has been met by a classification sufficiently elastic to find a place for any new development that may arise in the future.

The scheme of classification is based upon the two great principles of time and evolution. It begins with the ancient history of the earth, dealing first with the minerals because they are built of the elemental bodies, then comes the story of the rocks built up of minerals, and variously modified by earth heat and earth-movement, and the agents generally at work on the surface. Next follows the history of life as revealed in the rocks, in its three great stages of evolution, Primary, Secondary, and Tertiary, the series ending with the groups illustrating existing nature, plants, animals and man.

SCHEME OF GENERAL CLASSIFICATION IN THE MUSEUM.

Modern History of the Earth (Geography)	(VI) Animals	(VIII) Man	(VII) Plants	(VIII) History Anthropology Ethnology (VII) Botany (VI) Zoology
Ancient History of the Earth (Geology)	(V) Tertiary Life (Cainozoic)			(V, IV, III, II, I) Geology
	(IV) Secondary Life (Mesozoic)			(V, IV, III) Palæontology
	(III) Primary Life (Palæozoic)			
	(II) Rocks			(II) Petrology
	(I) Minerals			(I) Mineralogy

In dealing with the third of the great periods of life, the Tertiary, the evolution of the higher mammalia is the clue to the definition of the successive stages, which I originally applied to Europe, in 1870. It applies equally to the whole world if the living mammalia of each zoological province be taken as the starting point: the indigenous Eutheria for Asia, Africa and North and South America and the Metatheria for Australasia.

There is no break in the sequence of the Tertiary fauna and flora, from the earliest stage to the present day, that is sufficient to allow of a hard and fast line between geology and history. The continuity is so clear that the present phase of nature must be viewed as the current, but not necessarily the last of the Tertiary changes. We are living in the Tertiary, and the story of Modern Man begins in the remote Pleistocene stage of the same period.

TABLE OF THE DIVISIONS OF THE TERTIARY PERIOD.

Definitions.	Characteristics.
HISTORIC in which the events are recorded in history.	Modern Types of Mankind. Man the master of the World.
PREHISTORIC in which man has multiplied exceedingly. Domesticated plants and animals. Wild Eutheria of living species with the exception of Irish Elk.	Modern Types of Mankind. Cultivated fruit and cereals. Domestic animals. Wild Eutheria of living species.
PLEISTOCENE in which living species of Eutheria are more abundant than the extinct species. Man appears.	Extinct Types of Mankind. Modern Type. Living Eutherian species dominant at close of period.
PLEIOCENE in which living species appear in an Eutherian fauna mainly of extinct species.	Living Eutherian species present. Extinct species dominant. Extinct genera well represented.
MEIOCENE in which the alliance between living and extinct Eutheria is more close than in the preceding stage.	No living Eutherian species. Living Eutherian genera appear. Extinct genera dominant.
OLIGOCENE in which the alliance between extinct and living Eutheria is more close than in the Eocene.	No living Eutherian genera. Living families and orders. Extinct families and orders numerous.
EOCENE in which the Eutheria are represented by living as well as by extinct families and orders.	No living Eutherian genera. Living families and orders. Extinct families and orders dominant.

This classification meets the present demands of science, and is sufficiently wide to include all branches of the study of Man, as well as of Nature. Had the Manchester Museum been arranged on purely natural history lines, like that of the British Museum, there would have been no place for Egypt, or for those collections which will ultimately form centres for the study of anthropology, ethnology, and prehistory. It is of a new type, ready for use in the new England that is now in the making. It is unnecessary to deal with its value in strengthening the natural history teaching in the University. It is sufficient to say that without it the present high standard could not have been achieved. Outside the University it has helped to educate the general public by free demonstrations, addresses and lectures, given by the staff of the Museum and University. These began in the old Natural History

Museum in Peter Street, in 1870, and have now grown into a scheme specially intended for workers who are engaged all day and can only attend on Saturday and Sunday. It has made the Museum a living force in education. I look upon my share in this work as the most interesting and fruitful part of my teaching in Manchester.

The Museum has also become a centre of attraction to various institutions of working men, and clubs and other organisations of Lancashire and Cheshire. It has also along with the Art Galleries been of service to the Education Committee of the Manchester Corporation, in the instruction of the primary and secondary schools [1] by teachers especially trained by the staffs of the Museum and Art Gallery, with so much success, that Museum and Art courses are now fully recognised as part of the education of the people. [2]

I take this opportunity of calling attention to this new and progressive measure of the Education Committee, in recognising the value of Museums and Galleries in their courses of study. Their example will without a doubt be followed ultimately by the educational authoritives throughout the country.

The Manchester Museum is now one of the leading Museums in Britain, remarkable for its special collections, and is growing so fast, mostly by private gifts, that it will be necessary in the future to add an additional block, not only for the specimens, but for laboratories for the classes of the Education Committee.

From all these things, it may be concluded that the Manchester Museum is doing its share in raising the educational standard, both in the University and outside among the people. It has become what it is by the co-operation of the University with the City, and by the combination of the collections made by various societies and indi-

[1] At present 2000 children are under instruction in the Museum.

[2] "The visits to the Museums and Art Galleries for lessons in Natural History, Geology, Botany, Egyptology, and Art, have proved exceedingly interesting and valuable. The children look forward to these visits. Many of them have long distances to cover and, considering the severity of the weather, the attendance has been very good indeed, and is the best proof of the esteem in which the lessons are held. During the lessons the children are keen, curious, and inquisitive, and betray an intelligent interest which is very pleasing. The educational value of these lessons is great. They are undoubtedly broadening the children's outlook, introducing them to new worlds of ideas and giving them a new view of the wonderful world in which they live. The inauguration of the system of various classes in the available institutions of Science and Art in the City, thereby bringing their resources to the knowledge of the children, and establishing a connection between them and the City's education, is one of the obvious and possibly permanent benefits of the present situation. It is felt that when the war is over. this section of the work should be placed on a sure basis and facilities provided to enable the children to benefit from these great storehouses of knowledge."—*SPURLEY HEY, Director of Education, Report, June, 1917*, pp. 22-3.

viduals into one central organisation, aided by the generous support, financial and other, of the leading citizens.[1]

In common with the University it is of a new type intended to meet the situation in Manchester. The organisation is sufficiently elastic to be applicable to all other places where the museums are not in touch with the education of the people, and on a scale great or small, depending on the local conditions.

The study of the whole field of Nature is placed in the Manchester Museum, within the reach of the people. In the next section, I shall deal with the question how far can the fields of art and industry be covered by the development of existing or the founding of new institutions.

Manchester is now in a better position than it was in 1869 with regard to Natural History, and offers better facilities for development in other directions. Then the success was due to the co-operation of the Owens College with the Geological and Natural History Societies aided by the public spirit of our citizens—R. D. Darbishire, Thomas Ashton, and Cosmo Melvill and others. Now we can reckon on the support of the University and of the Corporation in an effort to meet the needs of Manchester with regard to art and industry, to say nothing of the large body of citizens interested in these questions. The public spirit in Manchester now is not less than it was then, while the need for action is far greater, in view of the situation created by war.

V.—Art in Manchester at the Present Time.

Manchester contrasts with all other cities of equal importance in the civilised world in the fact that it has no central Institution of Art adapted for modern requirements. The existing Art Galleries are devoted mainly to painting and sculpture, and the applications of Art to industry are either absent, or so inadequately represented, or so isolated from kindred objects, as to be of little use for systematic study. The workers and craftsmen generally in this city look in vain for standards by which they can measure the artistic value of their work, and learn how to combine beauty of form and of colour with the needs of modern life. Art is practically separated from handicrafts, and the best work done by the best men is a closed book to the great mass of our citizens.

The establishment of the Ancoats Museum, by Mr. T. C. Horsfall, is a noble effort to mitigate this evil, and to raise the standard of art and life in a poor quarter of the City.

[1] We owe the main buildings and Natural History laboratories to Mr. Thomas Ashton, to Mr. R. D. Darbishire, as representing the Whitworth Trustees, and to the other contributors, the Egyptian Block to Mr. Jesse Howarth, and the applied Geology Annexe to the Geological and Mining Society of Manchester, and to other benefactors interested in the applications of geology to mining.

The Municipal School of Art places within the reach of the art students some of the masterpieces of applied art, but has little, or no direct influence on the workers who cannot attend the classes. The only art institutions open to the public are the Municipal Art Galleries and the Whitworth Institution. Both are well organised, and made intelligible by public lectures and addresses, and both have been utilised by the Education Committee for the instruction of the primary and secondary schools. In neither, however, can the general public find the wide education in art, such as is offered by the Science and Art Museum at Edinburgh, or the Municipal Galleries of Aberdeen, Nottingham, Bristol, Birmingham, or Liverpool. They rank immeasurably below those of the principal cities of the Continent and of the United States.

It may be assumed that our need in Manchester of institutions for teaching from the things themselves is practically that of London. There the galleries of the British Museum grew round the library, and it was found necessary to establish sections of Greek, Roman, Assyrian and Egyptian Art. At a later time new galleries were added to include ethnology and pre-historic and mediæval antiquities. The exhibition of pictures was left to the National Gallery, and other institutions such as the Tate Gallery, which have been founded since. It was, however fully realised in 1851 that galleries of paintings and sculpture did not satisfy the needs of art and industry. To meet these the Museum of Science and Art was founded at South Kensington, on German lines, through the influence of Prince Albert, and in close connection with the Board of Education. We cannot obviously have in Manchester galleries on the scale of those in London. We can only be guided by our local needs. The place of the National and the Tate Galleries in London is filled here by the existing art galleries, and certain sections of the British and South Kensington Museums indicate the direction which our new development of art should take. The best examples, however, are to be found on the Continent, in Berlin, Hamburg, Munich and Cologne, as is pointed out in the Report to the City Council of the Art Gallery Committee in 1905, after the visit of their deputation to the Continent. In these as "in most other German towns efforts are made to encourage the application of art to industry, to inculcate good craftsmanship, as well as to give refined pleasure, to improve the standard of taste, and foster the love of the beautiful." If we are to maintain our place in the world, we must, to say the least, offer to our citizens the same facilities for education that are enjoyed by our rivals and enemies.

This report has been before the City Council for twelve years, and the Art Gallery question still remains unsettled, to the injury of the higher interests of the city, and especially of the workers, who have the right to demand the opportunity of educating themselves by the study of things. It is more important for labour than for any other class, that the galleries should be available as soon as possible after

the war. The site and the plan should be decided without further delay. We can see then how far our present collections can be enlarged, and supplemented by private benefactors, and we can prepare the collections for their places in the new buildings. The preliminary work in the Manchester Museum occupied ten years, and the organisation of the new galleries will not be completed in a short time.

VI.—Organisation of Collections for the New Art Gallery.

The scheme for the organisation of an Art Gallery in a new central institution, adopted by the Art Gallery Committee in 1902, is sufficiently wide to cover the whole field of Ancient and Modern Art. It consists of the following sections :—

Section I. Egyptian and Assyrian.—The Egyptian collection now in the Manchester Museum, places the study of Egyptian Art and life within the reach of the public. It therefore need not be duplicated here. It would not be difficult to add to the Egyptian collection specimens and casts sufficient to illustrate Assyria. The Assyrian Art is however so closely allied to Persian that it would go naturally into Section III.

Section II. Mykenæan, Greek and Roman.—The explorations by Schlieman in Troy, and Evans' work in Crete, have revealed the presence of a high civilisation in the Eastern Mediterranean, ranging backwards from the 12th to at least 25th century B.C., with an influence extending westwards through Italy and Spain, eastwards into Asia Minor, and northwards over the greater part of Europe. It is indigenous and quite separate from that of Egypt, although there were close commercial relations. It is from Mykenæan art that the Greeks got their inspiration. The scenes illustrating the hunting and taming of the great wild ox, the Urus, done in repoussé, on two golden cups, found in a tomb at Vaphio in Sparta, and the well-modelled bulls on the walls of the palace at Knossos, and the pose of the ivory statuette found at the latter place, indicate beyond all doubt the source of the highest type of Greek Art. We have the nucleus of a Mykenæan collection in the admirable facsimiles now stored in the Whitworth Institution. It would not be difficult to develop this into a series that would go into its natural place next to the Greek and Roman groups, and be of equal value to the students of art, and of history.

Section III. Eastern or Oriental.—The third, or Oriental Section will illustrate the sources from which so many of the designs used in the West have been derived. It should include Chinese, Japanese, Burmese and Siamese art, as well as that of India, Assyria, and Persia. We have still much to learn from the East, and it is specially important that we should learn as quickly as possible, when we consider the drift

of events by which our intercourse with the East is becoming closer than it ever has been in the past. For this section there are the materials in the existing galleries, and in the private collections that are available. The only difficulty to be anticipated will be in the exclusion of objects in which art is not the first consideration. If ethnology or anthropology be admitted it will be as the letting in of water.

SECTION IV. WESTERN OR OCCIDENTAL.—The Western or Occidental section constitutes the last of the four main groups. It should be confined to mediæval and modern art—to painting, and applications of art to stone, metal, wood, pottery, glass and fabrics, giving under each head examples of the best art work that can be obtained.

SECTION V. SPECIAL GROUPS.—To these sections must be added a special group of exhibits whether they be artistic or not that throw light on the life in Manchester in the past—such as "Old Manchester," now in Queen's Park Gallery. It will grow as rapidly as "Old London" has grown in the metropolis, and will appeal as strongly to the civic patriotism of the citizens. It will be of special value to the schools in the district.

A great central Art Institution on these lines will be of high educational value in Manchester to all classes and more especially to those who are engaged in the industries of the district. It will place our workers on equal terms in art with our rivals who have enjoyed similar institutions for many years. It will not, however, meet the needs of the manufacturers, merchants and workers generally, who look for the best examples of mechanical processes, and handicrafts. These can only be exhibited in an Industrial or Technical Museum, such as those at Hamburg and Washington. The machinery for building up such an institution are ready to hand in Manchester.

VII.—AN INDUSTRIAL OR TECHNICAL MUSEUM IN MANCHESTER.

We may learn from past experience the best steps to be taken in organising a new Industrial Museum. In the formation of the Manchester Museum, the Owens College, and afterwards the University, was a centre around which the collections were organised for teaching. It was realised from the very first that without the voice of the teachers the Museum would be a closed book to the public, and practically useless in general education. We have a similar centre in the Municipal Technical College, in which large collections are now being accumulated for use in the classes. It would not be difficult to use these as a nucleus for a great Museum, of equal service to students and the general public, especially to the workers who cannot attend classes, and standing in the same relation to the College of Technology as the Manchester Museum to the University. The organisation would naturally follow the teaching, and take such shape

as may be best fitted to meet the wants of the workers and manufacturers. The Education Committee of the Corporation have already made a new departure in using the Manchester Museum for the instruction of children; they have now the opportunity of placing higher standards of work within the reach of the workers, to the great advantage of industry.

VIII.—A New Centre of Music.

There is yet another direction in which we may look for increased facilities for the higher culture. The munificent offer of a quarter of a million for an Opera House, if an adequate site can be found, opens out the opportunity for the establishment of a new centre of music. It is to be hoped that it will materialise and take the form of one great institution, linked with the Royal College of Music, and closely connected with teaching, as in the three other institutions dealt with in this essay. The scheme will certainly be supported by the many lovers of music in this City.

IX.—General Conclusions.

The scheme now laid before the Society, if carried out, will cover the whole circle of education in Manchester. It will link together the University, the Municipal Schools of Art and Technology, the Primary and Secondary Schools, as well as the various Mechanic Institutions, and other organisations within and without Manchester. It is also in harmony with the general drift of education towards the study of things as well as of books. Its success is assured, if the various bodies concerned agree to co-operate and to adopt the principle of give and take, and thus prevent overlapping and waste of energy. Each should devote itself to the carrying out of that part of the scheme for which it is best fitted. It will be long before it can be completely carried out. The Manchester Museum grew into its present shape in the course of forty-eight years. It must further be noted, that only those parts can be realised in the near future that meet the pressing educational needs of raising the standards of art and industry among the people. Hitherto, the workers, as compared with the more leisured and wealthier classes, have not had equal opportunity of learning, and have had no chance of becoming more efficient by the study of the work of others. The policy of putting an end to this unfortunate situation will, beyond a doubt, be supported by those citizens whose forebears founded the University, the Manchester Museum, and the Art Galleries, and other public institutions for the good of the City. The initiative lies with the Corporation. When this, or some such scheme, is carried out—and that it will ultimately be carried out, I have no doubt—Manchester will have a more complete system of education for the people than any other industrial centre in Britain.

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IV. "On the Dorsal Mesenteric Filaments in the Siphonozooids of Pennatulacea."

By Constance M. Lightbown, M.Sc.

(Communicated by Professor S. J. Hickson, M.A., D.Sc., F.R.S.)

(Received and read November 13th, 1917.)

Nature of Investigation.

In the literature of the order Pennatulacea little attention has been paid to the matter of the occurrence of the two dorsal mesenteric filaments in the siphonozooids. The first and most exhaustive examination of their distribution was made by Kölliker in 1872. In 1884 E.B. Wilson examining mesenteric filaments in the Alcyonaria generally, while adding nothing to our knowledge of their occurrence in this order, summarised Kölliker's research by the following list :—

A. *Zooids with filaments.*
Pteroeides (Zooids of "Zooidplatte")
Pennatula
(Ptilosarcus =) Leioptilum *
(Halisceptrum =) Virgularia
Pavonaria
(Halipteris =) Pavonaria
Funiculina
Kophobelemnon
(Policella =) Veretillum
(Stylobelemnon =) Cavernularia

* The generic names used by Hickson are added at the right hand side.

B. *Zooids without filaments.*
Pteroeides (Ventral Zooids, Zooids of the "Kiel" and of the upper face of the leaves)
Leioptilum
Sarcophyllum
Virgularia
Acanthoptilum
Renilla (Wilson 1884, page 18)

This statement however, as recently pointed out by Professor Hickson, does not cover the whole facts of the case. "Since that "date Niedermeyer (1911, p. 36) has stated he could not find the "mesenteric filaments of *Pteroeides griseum.* On examining a "series of preparations of *Pt. malayense*, *Pt. caledonicum*, *Pt. "timorense*, and *Pt. argenteum*, I could find no trace of dorsal "mesenteric filaments, but in a similar preparation of *Pt. "Steenstrupii* they were present and of considerable size. In the "genus *Pteroeides* therefore they are sometimes present and some- "times absent. This is also true for *Umbellula* and *Pennatula.* In "the large siphonozooids of the petaloid areas of *U. Carpenteri* "these filaments are present and well developed but in the small "siphonozooids of the stem and stalk they are absent. In the "siphonozooids of *Pennatula phosphorea* (Marshall 1882, p. 46) "they are present and also in those of *P. grandis* but in the "siphonozooids of *P. Murrayi* they are absent." (Hickson 1916, p. 10). Mesenteric filaments have been recorded for a few other isolated species by recent writers as noted in the text of this paper.

This research therefore was undertaken to investigate the distribution of these filaments in the siphonozooids of the order Pennatulacea. For this purpose Professor S. J. Hickson most kindly placed at my disposal the whole of his preparations of the Pennatulacea from the Dutch "*Siboga*" Expedition and many specimens from his private collection.

METHODS.

In all species the siphonozooids were first examined whole, by cutting out a piece of the body wall or leaf and dissecting away the underlying tissue, slowly decalcifying in a weak solution of nitric acid in 70 per cent alcohol, and staining with Grenacher's haematoxylin. Where further examination was required transverse or longitudinal serial sections (5μ — 6μ thickness) of the siphonozooids were made, and in these also Grenacher's haematoxylin was found to give the best results. In many species, notably in those of *Anthoptilum*, sections in which this stain was used showed a distinct double stain when washed in acid alcohol, the ectoderm of the stomodaeum and filaments appearing bright red, all other endodermal and mesodermal tissues bluish purple. This red stain however faded to a uniform purple on neutralising with alkaline alcohol, or even on exposure to sunlight; hence, in most of the permanent preparations the mesenteric filaments are not so strikingly contrasted with other structures as at the first examination.

Where the above methods failed to reveal filaments by reason of the contracted condition of the tissues, or of the presence of foreign matter in the coelenteric cavities, it was found that their presence could be demonstrated in longitudinal sections of the siphonozooids about 0.5 m.m. in thickness, cut by hand from a piece of tissue previously hardened for two or three hours in absolute alcohol.

Structure of Siphonozooids.

The siphonozooids of Pennatulacea are distinguishable from the autozooids by reason of their lack of tentacles (with the exception of certain zooids in *Umbellula* and *Chunella* which possess one tentacle) : the presence of a wide ciliated groove, the siphonogylph, down the ventral length of the stomodaeum : the comparatively slight development of the eight mesenteries : and the absence of longitudinal retractor muscles and gonads on the mesenteries. Mesenteric filaments are never found on the six ventral mesenteries ; they may or may not occur on the dorsal mesenteries.

The structure of the dorsal filaments and their ectodermic origin is well described by Wilson (1884, p.12) and little need be added to his account.

It may be noted throughout the order that there is extraordinarily little variation in the structure and shape of the filament : the Y-shape in transverse section is constant, the two lateral lobes containing nuclei which stain deeply, the medium groove appearing clear. The diagrams given are typical for many species of the order. (Figs. I. and II.)

There is a slight variation in the width of the filament in different species, and to a greater extent in the length ; also in certain species the filaments appear straight or slightly curved, and in others they are considerably convoluted. How far this latter condition is natural, or to what extent produced by killing and fixing I am unable to state. It is recorded of fully expanded living polyps of *Alcyonium* or *Paralcyonium* (Wilson 1884, p.13) that the ventral endodermic filaments constantly change their form, being thrown into convolutions by the contractions of the mesenteries, but "the straight ectodermic filaments present a very different appearance." If this is correct for the siphonozooids it might be expected that the part of the mesentery below the stomodaeum would shew signs of contraction in the tentacular zooids of *Umbellula Carpenteri* for example, but there is no appearance of such contraction. Marshall figures a siphonozooid of *U. gracilis* (1883 Plate XXV., fig. 33) with the filaments considerably coiled.

OCCURENCE OF FILAMENTS IN GENERA EXAMINED.

Where the number of species under consideration is limited and incompletely representative it is impossible to make any absolute generalisations: furthermore, subsequent re-classification may destroy their value to some extent. It will be noted that the submergence of two of Kölliker's genera creates anomalies in Wilson's list. The following conclusions then can be applied *only* within the limits of the investigation.

Mesenteric filaments are present, with the single exception of *Renilla*, throughout the siphonozooids of the more primitive genera, that is in those genera where autozooids and siphonozooids occur together on the rachis, or where the autozooids are arranged in very primitive leaves :—

LITUARIA	FUNICULINA
VERETILLUM	PROTOPTILUM
CAVERNULARIA	CHUNELLA
ACTINOPTILUM	UMBELLULA
ECHINOPTILUM	OSTEOCELLA
KOPHOBELEMNON	PAVONARIA
SCLEROBELEMNON	ANTHOPTILUM

In the Virgularias however the filaments are not developed in any species except *V. Schultzei* which is unique in the genus in having the siphonozooids on the leaves. In the genus *Pennatula*, the filaments were present in every species examined except *P. Murrayi*. For *Leioptilum* and *Pteroeides* no general statement can be made: the filaments are present in some zooids and not in others. In the latter genus the majority of species are without filaments in the siphonozooids, their presence being noted only in two. In *Acanthoptilum*, *Sarcophyllum* and *Scytalium* the filaments are entirely absent so far as these genera have been investigated.

A complete list of species examined will be found at the end of this paper.

FUNCTION OF THE DORSAL MESENTERIC FILAMENTS.

It has been shown that the ventral siphonoglyph of the siphonozooids produces inhalent currents of water into the canal system of the colony (Hickson 1883, Wilson 1884). The dorsal filaments on the other hand produce a current in the opposite direction, i.e. exhalent. Wilson suggests that the circulation thus set up is for the distribution of food (nutritive fluid) amongst the zooids of the colony (l.c. p.16). It is probable also that the circulation is for the purpose of keeping up active respiration in the colony. That the

siphonozooids are exhalent as well as inhalent in function is proved for *Pennatula rubra* by the observation of Mrs. Musgrave (Q.J.M. S. 1909, p.455) that "clouds of methylene blue squirted among them were immediately dispersed in an outward direction." The fact that *P. rubra* has mesenteric filaments appears to confirm the theory that these are exhalent in function.

It must further be noted that in a few species of Pennatulacea there occur large zooids recently named Mesozooids by Professor Hickson (1916, p.11) which are apparently exhalent in function. These mesozooids are characterised by having no tentacles, and "a large open stomodaeum with a weak siphonoglyph supported by eight mesenteries provided with strong muscle bands," hence the water is probably ejected by the forcible contraction of the zooids by means of these muscles. They are found in *Pennatula Murrayi*, *P. grandis*, and many species of *Pteroeides*. It is suggested by Hickson that the exhalent zooid of *Renilla* (Wilson 1883) may be of the same nature, also the "Scheitelzooiden" described by Jungerson (1888) at the distal end of the rachis of young *Pennatula phosphorea* colonies. Zooids resembling mesozooids occur on the ventral side of the rachis in *Sarcophyllum*.

Conclusions.

In view of the foregoing facts it appears probable that all the more primitive species are provided with dorsal mesenteric filaments which subserve the function of causing exhalent currents, and in the one genus of these families where filaments are lacking, namely *Renilla*, an exhalent zooid is present. It is possible that *Renilla* should be considered to be a specialised and not a primitive form, the exhalent zooid marking a certain degree of specialisation.

In the higher genera the mesenteric filaments are supplanted by zooids specially modified for the function of exhalence. This conclusion is tenable for the cases of *P. Murrayi*, *Sarcophyllum* and most of the species of *Pteroeides* where filaments are absent and mesozooids present. In other species of *Pennatula*, P. *phosphorea P. rubra*, *P. fimbriata*, where mesozooids are not developed, the dorsal filaments do occur.

In *Pennat. grandis*, *Pter. pellucidum*, *Pter. Steenstrupii*, mesozooids and mesenteric filaments in the siphonozooids are present together. As these species closely resemble others of their genera in all essential characters, it can scarcely be held that the persistence of filaments denotes a lower grade of development, or that with further evolution the filaments would disappear and the specialised mesozooids acquire the exclusive function of exhaling water. As far as *Pter. Steenstrupii* is concerned the presence of

filaments would appear to have some connection with the size of the colony, for this species is unusually fleshy. The two single rows of mesozooids may be inadequate to discharge the water from an exceptionally extensive canal system, and therefore the filaments may have been retained to promote efficiency in this respect.

As *Pter. pellucidum* is not more fleshy than most species of *Pteroeides* the same hypothesis cannot be advanced with equal weight. In this species however, according to Kölliker mesenteric filaments are present only on the zooid-plate of the lower surface of the leaves. In the fleshier *Pter. Steenstrupii* mesenteric filaments are present in the zooids on both sides of the leaf. The two species are similar (if one may judge from Kölliker's figure of *Pter. pellucidum* (1872, fig. 34, Taf. IV.) in that the siphonozooids of the leaves are not so densely crowded together as in other *Pteroeides*. If mesenteric filaments were common to all species at some point in the generic phylogeny, those species in which the siphonozooids were sparsely distributed would possibly tend to keep their filaments functional while mesozooids were evolving; where large numbers of siphonozooids were present many of these would at once become superfluous and the tendency for the filaments to degenerate would be established earlier. This may to some extent explain the presence of filaments in *Pt. Steenstrupii*, and in some zooids of *Pt. pellucidum*, the siphonozooids of the latter being more crowded than those of the former, but not so much as in other species. In the absence of any phylogenetic evidence on this matter, any hypothesis can only be put forward very tentatively.

Throughout the order it may be stated that generally the mesenteric filaments are present in the more fleshy species and absent in the slender forms. Thus the filaments are absent in *Scytalium* several species of *Virgularia* and *Pennatula Murrayi*. In *Virgularia mirabilis* where Marshall records the fact that it is the rule to find the top of the colony missing (1882, p.60) it has been suggested that water is ejected from the open ends of the longitudinal canals by the contraction of their walls, these open canals being analogous to exhalent zooids.

Filaments are present in *Funiculina* which is a very slender and delicate form, but as there still appears to be a certain amount of doubt whether the undeveloped zooids bearing only dorsal filaments are true siphonozooids perhaps this exception may be left out of consideration. In slender species the colony even when fully distended can hold but little water, and this could readily be expelled by contraction of the delicate muscles of the rachis, the specialisation of mesenteric filaments being unnecessary.

The presence of filaments in the comparatively slender form of *V. Schultzei* may be accounted for by the consideration that the

leaves which bear the siphonozooids have little muscular tissue whose contraction could drive the water out from the colony; filaments are therefore present to serve this function. In other species of *Virgularia* contractions of the rachis doubtless serve to eject the water which has been inhaled by the siphonozooids.

In some species of *Umbellula* siphonozooids are recorded in the basal bulb of the colony. It is not established beyond doubt that these possess mesenteric filaments, but if their presence be established it would be in accordance with the general statement made above. There is no reason to doubt that respiration goes on in this part of the colony, even if the normal position is buried in the sea-bottom mud or sand, and mesenteric filaments would promote the circulation of water in this fleshy region as in the tassel at the distal end, while the intermediate zooids of the very slender rachis would not require filaments.

Finally it may be suggested that in some cases it would be advantageous to use the presence or absence of dorsal mesenteric filaments as a character for classification. There is no reason to suppose that this anatomical character is not constant for a given species, and in cases where local environmental conditions produced some modification or variation in external character it might prove a valuable guide in identification.

Notes on Mesenteric Filaments.

Lituaria Hicksoni. Thomson and Simpson.

Siphonozooids mounted whole and viewed from the surface or from below showed no indication of filaments but transverse sections through the zooids shewed them to be present in every zooid. The average width was 0.048 m.m; most of the filaments were very definitely Y-shaped in section, but others which did not appear well preserved were more rounded and the medium groove was not well marked.

Veretillum malayense. Hickson.

Siphonozooids mounted whole showed no indication of mesenteric filaments. The specimen viewed externally seemed to be well preserved but the internal tissues were not in a sufficient state of preservation to determine whether filaments were present or not. In longitudinal section there were signs of cells in continuation from the stomodaeum but the characteristic structure of filaments was not evident.

V. CYNOMORIUM. Pallas.

In describing the character of the genus *Veretillum*, Kölliker (1872, p.331) states that mesenteric filaments are present. (It may be noted here that all Kölliker's statements on mesenteric filaments are made as a generic character: it must be assumed therefore that they apply to all the species whose descriptions follow, even though in some cases it appears doubtful whether the author has verified the statement for every species). Kükenthal and Broch describing the same species (1911, p.515) also mention their presence—"Die zwei dorsalen Mesenterialfilamente laufen bis zu dem Grunde der Leibeshöhle hinab."

VER. (POLICELLA) AUSTRALIS, Gray.

VER. (POLICELLA) MANILLENSIS, Kölliker.

Of these species the following observation is made:

"Die Zooide von Policella messen im Mittel in der Länge bis zum Ende des Magens 0.18 - 0.20 m.m., in der Breite 0.36 - 0.45 m.m., wovon 0.09 - 0.12 m.m. auf den innen mit Flimmern besetzten Magen kommen und zeigen ihre Mesenterialfilamente von 0.028 -0.032 m.m. Breite keine bestimmte Stellung im Vergleich zum Stocke. Die weiten Leibeshöhlen der Zooide ragen mit ihren Mesenterialfilamenten bis unter die Längsmuskeln der Cutis und gehen hier in ein spongiöses Gewebe über, dessen Abzugskanäle in den Zwischenwänden der Polypenzellen zu verlaufen scheinen." Kölliker, 1872 p.320.

CAVERNULARIA ELEGANS, Herklots.

According to Kükenthal and Broch, filaments are present on the dorsal mesenteries (1911, p.513).

C. OBESA, Milne-Edwards and Haime.

This species affords a marked contrast to *C. orientalis* being extremely fleshy and the siphonozooids densely crowded, rendering investigation difficult. The filaments are slightly coiled and run down the narrow zooid cavity closely parallel for an average distance of 0.42 m.m. or about $2\frac{1}{2}$ times the length of the stomodaeum. Kükenthal and Broch (1911 p.513) record the presence of filaments in the species.

C. ORIENTALIS, Thomson and Simpson.

The filaments here are exceptionally well developed, and are very readily perceptible owing to the transparency of the tissues of the colony. In most of the siphonozooids these filaments extend for an appreciable distance beyond the bases of the coelentera into the subjacent canals. In an average sized siphon-

zooid the total length of one of the filaments was 0.672 m.m. and of this a length of 0.192 m.m. projected beyond the coelenteric cavity. In all the siphonozooids of this specimen the filaments were fully extended and showed no convolutions or coils: seen from the external surface of the colony they curved out from the base of the stomodaeum, the two filaments forming an angle of from 45 -90 degrees.

C. PUSILLA, Herklots.

In describing this species under the name *Stylobelemnon*, Kölliker states that the siphonozooids have two mesenteric filaments. Recent writers however cast doubt on this observation: ". . . . auch Mesenterialfilamente vermochte ich meist nicht wahrzunehmen. Nach Kölliker (1872 p.350) sllen zwei Mesenterialfilamente vorhanden sein, doch reichte der Erhaltungszustand meines Materials nicht aus, um überall mit Sicherheit das Vorkommen dieser beiden, jedenfalls den dorsalen Septen zugehörigen Filamente wiederzufinden. Nur an ein paar Stellen habe ich diese dorsalen Mesenterialfilamente erkennen können" (K. and B. 1911 p.513). As I have had no opportunity of examining this species I am unable to add anything further to these statements.

ACTINOPTILUM MOLLE, Kükenthal.

This species is closely allied to the Cavernularias and similarly possesses well developed dorsal mesenteric filaments.

ECHINOPTILUM ECHINATUM, Kükenthal and Broch.

A specimen dredged by the "Valdivia" off Somaliland is described as having siphonozooids with straight powerfully developed dorsal septa bearing filaments (K. and B. p.518).

E. ELONGATUM, Hickson.

The filaments in this species are the longest observed in the genus and reach a length of 0.288 m.m.

E. MINIMUM, Hickson.

Mesenteric filaments short: 0.16 - 0.18 m.m. in length and average width 0.037 m.m.

E. ROSEUM, Hickson.

The filaments are narrow and only reach down for a distance equal to the length of the stomodaeum. As in the other species of the genera they are straight. *E. roseum*, *E. elongatum* and *E. minimum* are new species taken by the "Siboga" in the East Indian Archipelago.

KOPHOBELEMNON PAUCIFLORUM, Hickson.

The mesenteric filaments are here very much coiled up.

K. BURGERI, Herklots.

K. STELLIFERUM, Müller.

L. LEUCKARTII, Kölliker.

Filaments are recorded in the siphonozooids of these species (Kölliker 1872, p.303). The observation on *L. stelliferum* is confirmed by Kükenthal and Broch (1911, p.523).

SCLEROBELEMNON BURGERI, Herklots.

The filaments are very much coiled up, and in a preparation of the whole siphonozooids, are difficult to identify, being in most of the zooids hidden by the stomodaeum.

FUNICULINA QUADRANGULARIS, Pallas.

There is some doubt among writers on this genus as to whether the small zooids without tentacles occuring on the rachis are true siphonozooids or young autozooids.

Marshall says of them "They have only two mesenterial filaments, viz. those corresponding to the two long filaments of the polyps: like these latter they extend to the bottom of the body cavity. The remaining six mesenteries are present, but their free edges below the stomach are not thickened to form mesenterial filaments." (1882 p.19). It is further stated however—"in the younger specimens there appears to be a gradual passage from zooids to polypes, though whether zooids are in all cases destined ultimately to grow up into polyps must be left for the present undecided." Kükenthal and Broch consider the zooids in question to be siphonozooids (1911, p.527 and Fig. 100, Taf. XXVIII). In the specimen I examined there appeared to be no transition from siphonozooids to autozooids, and the smallest zooids with no tentacles bore well-developed dorsal filaments of typical structure (0.037 m.m. broad) and no others.

PROTOPTILUM CELEBENSE, Hickson.

In this species the mesenteric filaments are of the coiled type.

DISTICHOPTILUM.

No specimen of this genus has been available for investigation, and having found no reference to the anatomy of the siphonozooids in the literature of the genus, I am unable to make any statement with regard to mesenteric filaments. The species are more slender than Protoptilum but as filaments are so generally found in all these more primitive forms it is probable they occur here also.

Chunella gracillima, Kükenthal.

In his description of this species in the memoir of the "Siboga" Expedition (1916 p.112) Hickson describes the siphonozooids "found on the dorsal side of the swellings of the rachis that bear the autozooids," and mentions that in them the mesenteries are little developed, "but there appear to be two long mesenteric filaments connected with the stomodaeum of each siphonozooid." Further it is stated that siphonozooids were not found on the rachis between these swellings. Beyond confirming the observation of filaments and noting that they were somewhat coiled, I have made no further examination, but it would be interesting to determine whether the siphonozooids described by Kükenthal and Broch in the slender parts of the rachis between whorls of autozooids possess filaments or not.

Umbellula antarctica, Kükenthal.

The siphonozooids on the rachis possess considerably coiled dorsal mesenteric filaments.

I examined a single preparation, made from this "Siboga" specimen, of a piece of the body wall from the basal swelling of the stalk. This tissue was stained in borax carmine, which is not very satisfactory for the present purpose, but in it a few scattered siphonozooids were discernable. This point is of interest in view of the fact that their presence destroys the value of the morphological diagnosis made by Jungersen (1904 p.82) that "the zooidless part of the bulb corresponds to the peduncle (i.e. stalk) of other Pennatulacea, and the greater part of the stalk from the beginning is to be regarded as the rachis." This point is discussed by Hickson in the "*Siboga*" memoir (p.118). For the purpose of the present investigation I can make no dogmatic assertion on the presence of mesenteric filaments in these basal siphonozooids: certain rather yellowish sinuous bodies by the side of the stomodaeum in most of the zooids bear a strong resemblance to filaments, but the fact that they have absorbed little or no stain casts a certain amount of doubt on their identity, and from lack of material I am unable to make further preparations for confirmation. In my experience, whatever the state of preservation, mesenteric filaments stain as readily as the ectoderm of the stomodaeum, and to a greater extent than the epithelium and mesoderm of the surrounding tissue. Filaments would undoubtedly be of use in promoting circulation of water in this fleshy part of the colony.

Umbellula Carpenteri, Kölliker.

The siphonozooids of the "petaloid" region of this species possess filaments of unusually large size. The siphonozooids

average 0.3 m.m. in diameter, with a stomodaeum measuring 0.2 m.m. in dorsiventral diameter and every coelenteron appears to be almost filled with the large convoluted filaments, 0.096 m.m. in greatest width; so that at any level of a series of transverse sections a single filament may be cut through transversely two or three times, or may appear cut longitudinally for a length of .2 to .3 m.m.

In describing a specimen taken by the "*Discovery*" Hickson (1907 p.13) refers to the small siphonozooids from the upper part of the bulb, which he examined in transverse section, and says of these: "The specimen is not sufficiently well preserved to enable me to state definitely that the dorsal mesenteric filaments are present, but certain groups of darkly stained cells situated below the stomodaeum probably represent these structures." I have examined the preparations mentioned and though the material is not sufficiently well preserved to show any minute structure, the position and stained condition of these bodies justifies the supposition that they represent filaments.

U. GRACILIS, Marshall. = U. LINDAHLI, Kölliker.

Mesenteric filaments in the siphonozooids are described by Marshall for a specimen trawled by the "Triton" (1883 p.146) but the statement and accompanying diagram (Plate XXV. fig. 33) refer to the large tentacular siphonozooids towards the top of the rachis, and while the author mentions that the zooids decrease in size towards the base of the rachis, he does not state if filaments are present in all. Jungersen identifies the *U. Lindahlii* of Kölliker with the above species and confirms the observation of filaments (1904 p.77).

U. JORDANI, Nutting.

In this species also the filaments are well developed, being of considerable length, and coiled, though not to the same extent as those in *U. Carpenteri.*

OSTEOCELLA SEPTENTRIONALIS, Gray.

Siphonozooids in this large fleshy sea-pen occur scattered on the dorsal track of the rachis and between the leaves, and in all mesenteric filaments are well developed.

PAVONARIA FINMARCHICA, Sars.

PAVONARIA (HALIPT.) CHRISTII, Koren and Danielssen.

Of the first of these species Kölliker (loc. cit. p.242) referring to the siphonozooids, says "die ich als die zwei langen Mesenterialfilamente deute, die bei den Zooiden so vieler Pennatuliden sich finden:" of the second species which was described under the generic name *Halipteris* a similar observation is made (p.248).

ANTHOPTILUM GRANDIFLORUM, Verril.

The filaments are slightly sinuous and average 0.045 m.m. in breadth.

A. KÜKENTHALI, Hickson.

In a specimen of this species from the Indian Ocean, Mrs. Musgrave (1909 p.464) observed siphonozooids in the lower part of the stalk. Though small in size they had the usual structure of siphonozooids but differed from others of the colony in possessing no mesenteric filaments. It is interesting to compare this condition with that in *Umbellula*, where there is some evidence of the filaments being present in siphonozooids at the base of the stalk. The explanation may lie in the fact that in *Anthoptilum* a far greater number of large siphonozooids with well developed filaments is present in the colony, and these extend comparatively much nearer the basal bulb than in Umbellula. In *Anthoptilum*, therefore, the exhalent currents set up by the filaments of the siphonozooids of the rachis are sufficiently strong to discharge water from the stalk, whereas in *Umbellula* this is not the case, and filaments are necessary in the basal stalk zooids.

A. MALAYENSE, Hickson.

The filaments are here more slender than in *A. grandiflorum* but are considerably more coiled, and extend in some zooids to a depth of 0.5 m.m. from the surface of the colony. In examining the siphonozooids *in situ* this coiled mass of filaments is very striking.

VIRGULARIA GRACILLIMA, Kölliker.

In the genus siphonozooids are comparatively few in number. In this species they are situated on the rachis between leaves, and mesenteric filaments are absent.

V. GUSTAVIANA, Herklots.

In this species, which he described as *Halisceptrum*, Kölliker (1872 p.168) observes that the corners of the lower free end of the stomodaeum appear almost like mesenteric filaments, but expresses the doubt "doch habe ich mir nicht die Ueberzeugung zu verschaffen vermocht, dass diese Anhänge wirklich diese Bedeutung haben." It would be of interest if the occurence of short mesenteric filaments was definitely established in this species which is rather of a fleshy character and has a large number of siphonozooids. The same author describes fifteen species of *Virgularia*, and makes the general statement that mesenteric filaments are lacking. For reference, a list of these species is

appended, exclusive of species which I have personally examined and species synonymous with such.

VIRGULARIA GLACIALIS, Sars.
,, AFFINIS, (= V. Steenstrupii) Kölliker.
,, ELLISII, Gray.
,, ELEGANS, Gray.
,, PUSILLA, Verrill.
,, GRACILIS, Gabb.
,, ELONGATA, Gabb.

Confirmatory evidence of the lack of filaments in siphonozooids of the species listed would therefore be valuable.

V. JUNCEA, Pallas.

Siphonozooids do not possess filaments.

V. MIRABILIS, Lamarck.

An examination of longitudinal sections through the siphonozooids appeared to confirm the Marshalls' statement (1882, p.72) that the stomodaea are blind sacs. There is no indication of mesenteric filaments and if the above statement is correct the zooids would appear to be functionless. The specimen I investigated was however small in size, hence it is possible that with further growth the stomodaea might acquire an opening into the body cavities.

V. RUMPHII, Kölliker.

The siphonozooids occur in vertical rows between the leaves, and in them mesenteric filaments are entirely absent. It may be noted here that in the young zooids occuring in a groove near the base of the rachis well developed dorsal mesenteric filaments were found. This observation confirms the opinion expressed by Professor Hickson (1916, p.149) that these zooids are young or undeveloped autozooids. When mature, autozooids possess eight mesenteric filaments, but where development has been followed the fact has been established that the dorsal ectodermic pair are the first to appear. Accordingly, as mesenteric filaments are absent in mature siphonozooids, their occurence in these undeveloped zooids coupled with the fact of the presence of young gonads on the mesenteries, appears to place Hickson's interpretation beyond doubt.

V. SCHULTZEI, Kükenthal.

The species is remarkable in the genus in having the siphonozooids on the leaves, and in the fact of these siphonozooids being provided with short but well developed sinuous filaments.

PENNATULA FIMBRIATA, Herklots.

Filaments are present, being in some zooids slightly convoluted and in others practically straight; in the latter they extend in some cases as far as 0.064 m.m. beyond the lower edge of the stomodaeum.

P. GRANDIS, Ehrenberg (= P. BOREALIS, Sars).

In the normal siphonozooids large thick and much coiled filaments are present ; mesozooids are also present, occuring on the dorsal rachis at the edge of each leaf.

P. MURRAYI, Kölliker.

Mesenteric filaments are absent in the siphonozooids, but the species resemble *P. grandis* in having mesozooids, on being found at the edge of each leaf, in the same position as in the latter species.

P. PHOSPHOREA, Linnaeus.

Filaments are present, being long, straight and rather slender: maximum breadth 0.032 m.m., length up to 0.56 m.m. This confirms the observation of the Marshalls (1882, p.46).

P. RUBRA, Ellis.

The filaments are similar in size to those in the siphonozooids of *P. phosphorea*. In a few of the zooids, however, I was unable to find them ; it is possible they may have been accidentally dissected away with the mesodermal tissue in making preparations, or may actually have been present but obscured by mesodermal fleshy tissue. As the number of zooids in which filaments were not observed was comparatively small, the point is of little importance.

It may be noted here that in a surface examination of pieces of *P. rubra* from the Bay of Naples, I saw no evidence of the large zooid near the dorsal edge of the leaf which was described by Kükenthal and Broch for a specimen obtained from the Indian Ocean (1911, p.383).

LEIOPTILUM QUADRANGULARIS, Moroff.

The siphonozooids crowded on the dorsal side of the rachis and between the leaves, bear mesenteric filaments. Their presence is of interest in view of the fact that Kölliker found no filaments in *L. undulatum*, Verrill, from California and Mexico. Of *Leioptilum* and *Sarcophylum* this author says "In einem andern Punkte stimmen jedoch beide Gattungen überein, nämlich in dem Mangel der Mesenterialfilamente in den Zooiden. Von den lateralen Zooiden

hat jedes eine geräumige Leibeshöhle mit 8 Septa, die unterhalb des Magens in einen kurzen Kanal sich fortsetzt, an dem ich ebenfalls keine Filamente finde."

In *Ptilosarcus Gurneyi*, Gray, now called *L. Gurneyi*, Gray (*vide* Hickson p.188) Kölliker did find two mesenteric filaments "of tolerable length" and subsequently cited the occurence of them as one of the diagnostic characters of the genus *Ptilosarcus*. (1872, p. 368).

In the same writer's account of the British Museum specimen *L. sinuosum* (= *Ptilosarcus sinuosus*, Gray) there is no statement regarding the filaments of the siphonozooids, but in *L. Grayi* (= *Sarcoptilis grandis*, Gray) their absence is noted. (*l.c.* p.368).

SCYTALIUM BALSSII, Hickson.
,, MARTENSII, Kölliker.
,, SARSII, Herklots.

Filaments are absent in the siphonozooids of the three above species.

PTEREOEIDES ARGENTEUM, Ellis and Solander.
,, CALEDONICUM, Kölliker.
,, GRISEUM, Bohadsch.
,, MALAYENSE, Hickson.
,, SPECIOSUM, Kölliker.
,, TIMORENSE, Hickson.

Filaments are absent in the siphonozooids of all the above *Pteroeides* species.

PTEROEIDES PELLUCIDUM, Kölliker.

Siphonozooids situated on the lower surface of the leaves are stated to possess mesenteric filaments by Kölliker (1872, p.38) with the qualification—"Doch sah ich sie bei einzelnen Individuen auch fehlen und weiss ich nicht, ob denselben ein allgemeines Vorkommen, bei den verschiedenen Arten zuzuschreiben ist." In other zooids of the colony they are absent.

PTER. STEENSTRUPII, Kölliker.

The siphonozooids on the leaves of this species are not densely crowded in "plates" but occur scattered apart, some singly, others in small groups of six or fewer. Filaments are present in them on both upper and under surfaces of the leaf, and while these filaments are of approximately uniform breadth (0.023 m.m. — 0.018 m.m.) there is considerable variation in length (0.032 m.m. — 0.352 m.m.).

LIST OF SPECIES.

In the following list of species discussed in this paper, an asterisk denotes those which have not been personally examined.

The family names are omitted, but the grouping of genera is in accordance with the classification used by Professor Hickson (1916).

Genus and Species.	Locality.	Dorsal mes. fils. present.	Dorsal mes. fils. absent.
LITUARIA HICKSONII, Thomson and Simpson.	Molo Strait, E. Ind. Arch.	†	
VERETILLUM MALAYENSE, Hickson.	Bay of Bima, E. Ind. Arch.	doubtful	
*V. CYNOMORIUM, Pallas.	S. Africa.	†	
*V. (POLICELLA) AUSTRALIS, Gray.	Sharks Bay, Australia.	†	
* V. (POLICELLA) MANILLENSIS, Kölliker.	Philippine Is.	†	
*CAVERNULARIA ELEGANS, Herklots.	W. Coast Central Africa.	†	
C. OBESA, Milne-Ed. and Haime.	Andaman Is.	†	
C. ORIENTALIS, Thomson and Simpson.	Amboyna, E. Ind. Arch.	†	
*C. (STYLOBELEMNON) PUSILLA, Herklots.	Sicily.	doubtful	
ACTINOPTILUM MOLLE, Kükenthal.	Cape of Good Hope.	†	
*ECHINOPTILUM ECHINATUM, Kükenthal and Broch.	Somaliland.	†	
E. ELONGATUM, Hickson.	Kangeang Is. E. Ind. Arch.	†	
E. MINIMUM, Hickson.	S. Coast Timor, E. Ind. Arch.	†	
E. ROSEUM, Hickson.	Off Kei Is., E. Ind. Arch.	†	
*RENILLA MÜLLERI, Schultze.	Coast of Brazil.		†
KOPHOBELEMNON PAUCIFLORUM, Hickson.	Djilolo, E. Ind. Arch.	†	
*K. BURGERI, Herklots.	Japan.	†	
*K. LEUCKARTII, Kölliker.		†	
*K. STELLIFERUM, Müller.	Trondhjem fjord.	†	
SCLEROBELEMNON BURGERI, Herklots.	Molo Strait, E. Ind. Arch.	†	

Genus and Species.	Locality.	Dorsal mes. fils. present.	Dorsal mes. fils. absent.
FUNICULINA QUADRANGULARIS, Pallas.	W. coast Scotland.	†	
PROTOPTILUM CELEBENSE, Hickson.	Celebes.	†	
*P. CARPENTERI, Kölliker.	Atlantic.	†	
*P. SMITTII, Kölliker.	Atlantic.	†	
*P. THOMSONII, Kölliker.	Atlantic.	†	
CHUNELLA GRACILLIMA, Kükenthal.	E. Java Sea.	†	
UMBELLULA ANTARCTICA, Kükenthal.	near Saleyer, E. Ind. Arch.	†	
U. CARPENTERI, Kölliker.	Antarctic Ice Barrier	†	
U. GRACILIS, Marshall.	N.W. coast Scotland	†	
U. LINDAHLII, Kölliker.	Greenland.	†	
U. JORDANI, Nutting.	S. Celebes.	†	
OSTEOCELLA SEPTENTRIONALIS, Gray.		†	
*PAVONARIA FINMARCHICA, Sars.		†	
*P. (HALIPTERIS) CHRISTII, Koren and Danielssen.	off E. coast England.	†	
ANTHOPTILUM GRANDIFLORUM, Verrill.	Cape of Good Hope.	†	
A. KÜKENTHALI, Hickson.	Indian Ocean.	†	
A. MALAYENSE, Hickson.	off Flores Is., E. Ind. Arch.	†	
VIRGULARIA GRACILLIMA, Kolliker.	E. Buton Strait, E. Ind. Arch.		†
*V. (Halisceptrum) GUSTAVIANA, Herklots.	China.		†
V. JUNCEA, Pallas.	Saleyer, E. Ind. Arch.		†
V. MIRABILIS, Lamarck.	W. coast Scotland.		†
V. RUMPHII, Kölliker.	Menado, E. Ind. Arch.		†
V. SCHULTZEI, Kükenthal.	Cape of Good Hope.	†	
PENNATULA FIMBRIATA, Herklots.	S. coast Timor, E. Ind. Arch.	†	
P. GRANDIS, Ehrenberg.	Faero Is.	†	
P. MURRAYI, Kölliker.	coast Timor		†

Genus and Species.	Locality.	Dorsal mes. fils. present.	Dorsal mes. fils. absent.
P. PHOSPHOREA, Linnæus.	Naples.	†	
P. RUBRA, Ellis.	Naples.	†	
*ACANTHOPTILUM AGASSIZII, Kölliker.	off French Reef, Gulf Stream.		†
*A. POURTALESII, Kölliker.	off Carysfort Reef, Gulf Stream.		†
*LEIOPTILUM GRAYI, Kölliker. (=SARCOPTILIS GRANDIS, Gray).	probably Australia.		†
*L. (PTILOSARCUS) GURNEYI, Gray.	California.	†	
L. QUADRANGULARIS, Moroff.	Hecate Strait, Brit. Columbia.	†	
*L. SINUOSUM, Kölliker.	California.		undetermined
*L. UNDULATUM, Verril.	California.		†
SCYTALIUM BALSSII, Hickson.	Timor, E. Ind. Arch.		†
SC. MARTENSII, Kölliker.	Timor.		†
SC. SARSII, Herklots.	Java Sea.		†
*SARCOPHYLLUM AUSTRALE, Kölliker.	Australia.		†
PTEROEIDES ARGENTEUM, Ellis and Solander.	New Guinea.		†
PT. CALEDONICUM, Kölliker.	Amboyna, E. Ind. Arch.		†
PT. GRISEUM, Bohadsch.	Naples		†
PT. MALAYENSE, Hickson.	E. Borneo Bank.		†
*PT. PELLUCIDUM, Kölliker.	Philippine Is.	†	
PT. SPECIOSUM, Kölliker.	Molo Strait.		†
PT. STEENSTRUPII, Kolliker.	Tandjong Priok, Java.	†	
PT. TIMORENSE, Hickson.	S. coast Timor.		†

EXPLANATION OF ILLUSTRATIONS.

Figure I. Siphonozooid of *Pennatula phosphorea* in longitudinal section A, with stomodaeum whole; B, with stomodaeum bisected in dorso-ventral plane.

Figure 11. Siphonozooids of *Echinoptilum minimum* in transverse section, cut at three levels. A, section through stomodaeum; B, section below stodaeum; C, section near base of coelenteron.

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REFERENCE LETTERS.

autoz ... ... autozooid
c. ... ... coelenteric cavity
d.m. ... ... dorsal mesentery
d.m.f. ... ... dorsal mesenteric filament
e. ... ... epithelium
m. ... ... mouth
si. ... ... siphonoglyph
st. ... ... stomodaeum
v.m. ... ... ventral mesentery

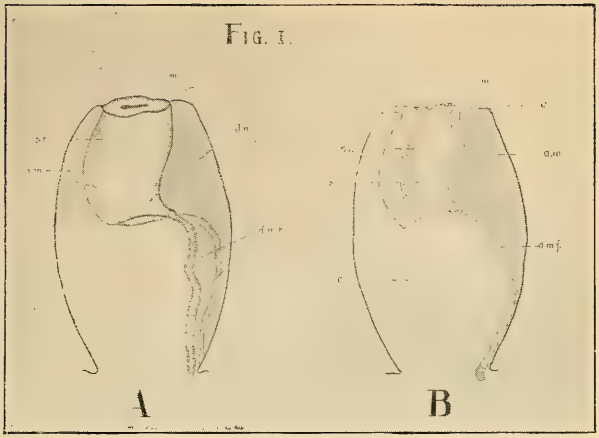

FIG. I.

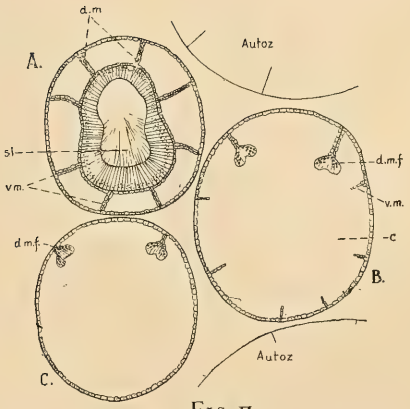

FIG II.

Manchester Memoirs, Vol. lxii. (1917), *No.* 5

V. Somatose.

By William Thomson, F.R.S.E., F.I.C., F.C.S.

(Received and read January 8th 1918.)

The substance sold under the name of Somatose was invented by a German and prepared by a well-known German firm (The Bayer Co., Ltd.) some years ago. It was put up in small square tins containing 2 ozs. and sold at 3/2 per tin, i.e. 25/4 per lb. It was claimed for it, that although taken in small doses of two or four level teaspoonfuls per day for adults, equal to 6 to 12 grammes, i.e. from one-fifth to two-fifths of an ounce, it rapidly increased the weight of the person taking it, and was specially recommended for invalids, and for all sorts of disease.

At one time, probably on the reputation of the name of the manufacturer, it was largely used and frequently recommended by medical men.

Somatose was manufactured from the refuse left after extracting meat with warm water. The solution thus obtained, after concentration, constituted the meat extract which is a good tonic, but cannot be regarded as a food.

The insoluble refuse or fibrine was no doubt suitable for food, if used at once, or if preserved in tins, although it would be somewhat tough, but it was not always so used in the Argentine. It was often disposed of by being thrown into the sea.

The process devised by an ingenious German was, to heat the fibrine with water under a pressure of 90 lbs to the square inch i.e. at a temperature of 320 degrees Fahrenheit for some time, when a large part of it went into solution. The solution was filtered from the insoluble tissue and fat and evaporated to dryness. This left a brittle brownish residue which on being powdered constituted Somatose.

The following gives the results I found by treating 100 parts of Raw Lean Beef calculated on the dry materials:—

	Per cent.
Soluble Matter removed by digesting the meat in warm water, then boiling the meat extract to coagulate the albumen and filtering	19.21
Soluble Matter obtained by heating the insoluble part from the above, with water to 320 degrees Fahrenheit (under a pressure of 90 lbs. to the square inch) ("Somatose")	51.84
Insoluble matter from above treatment { Non-fatty material.. ...	9.07
{ Fat	19.88
	100.00

According to some of the most recent researches, any food material to be of full value must contain "Vitamines"—principles which are destroyed by excessive heat in cooking, or which may be rubbed off the outside of the grains of rice (where it exists) in improving its appearance by means of "polishing;" this "polished" rice when eaten being regarded as the cause of the disease "beri-beri" through the rice having been thus deprived of its vitamines.

The process of digestion in the stomach and intestines are exceedingly complicated. They depend largely on certain enzymes secreted in the salivary glands, the stomach, the pancreas, and the intestine, which break down the albuminous and other constituents of the food to elementary molecules, and on the properties of other enzymes which re-build these unfolded constituents or elementary molecules into the complicated structures which constitute the various organs of the body.

The structure of food of any kind is such that the various enzymes are liable to act on these delicately constructed molecules of which the food is composed.

Leaving the question of vitamines out, does it seem probable that on heating an albuminoid substance of the nature of fibrin to a temperature of 320 degrees Fahrenheit for an hour, that the delicate molecules would remain in the same condition as they existed in the original fibrin? To get some information on this point I heated a solution of cane sugar to the same temperature with the result that the sugar was entirely destroyed and blackened, and there resulted what appeared to be a mixture of charcoal and water. It is obvious therefore—disregarding the presence of certain delicate organic bodies called Vitamines—that in the case of cane sugar, the actual molecule is destroyed by heating to 320

degrees Fahrenheit, and it would certainly then cease to have any nourishing properties.

The reason I came to study this problem was that a certain Port Wine was alleged to contain what was an equivalent in nourishing properties to 7 per cent. of its weight of lean meat. This so-called nourishing material put into the wine was Somatose which dissolved almost completely in it, and after settling or filtering, the wine, was obtained clear with the Somatose in solution.

To arrive at the equivalent in Somatose of lean meat, the percentage of Nitrogen in both were determined, and it was assumed that the equivalent of Somatose in Nitrogen was equal to the equivalent of lean beef in Nitrogen for feeding purposes. It need hardly be mentioned that this supposition is utterly fallacious, because it might be similarly argued that a small quantity of Urea, which is rich in Nitrogen and has no food value would be equal as a food to a large quantity of lean meat.

Somatose was obviously a complicated organic body. The following analysis of it is given by A. R. Tankard :—

	Per Cent.
Water	14.25
Alkali Albumin (precipitated from the cold aqueous solution by Acetic Acid in slight excess)	21.83
Coagulable Albumin (precipated from the filtrate by boiling).	3.40
Albumoses (precipitated from the filtrate by Zinc Sulphate).	33.96
Peptones (precipitated from filtrate by Bromine) ...	3.06
Meat bases (Calculated from excess Nitrogen by factor 3.12)	2.62
Ash (having an alkalinity equivalent to 1.91 per cent. Sodium Carbonate, Na_2CO_3)	5.30
Difference (not accounted for)	15.58
	100.00

This analysis of such a complicated organic substance cannot be regarded as satisfactory, so I give as follows the analysis by Luff and Sir Thomas Stevenson :—

	Per cent.
Deutero-Albumose	51.60
Hetero-Albumose	13.40
Peptone	5.00
Water	11.04
Mineral Matter	5.02
Difference (not accounted for)	13.94
	100.00

These figures do not add anything to our knowledge as to its food value.

The question then arose as to how it was possible to determine whether it possessed any, and if so, what food value, and I concluded that the only way was to feed animals with it as part of their food, and weigh them from time to time, to find whether they gained weight as compared with other animals eating the same kind of food to which an amount of lean beef had been added, equivalent in Nitrogen content to the Somatose. As I had only a small quantity of Somatose at my disposal I could only afford to feed small animals with it, and I decided to use tame mice.

It required a series of trials to find the best method of feeding them. If the food were left in an open dish the mice scattered it and some was wasted. I finally put the food at the bottom of a small wide mouthed bottle which was laid on its side, so that the mice had to put their heads inside the bottle to get it; this prevented the scattering, and the food was then reduced in quantity to that which an average mouse would eat in 24 hours.

The food supplied to each consisted of 2 grammes of Oats per 24 hours, the other constituents of the food being altered in accordance with their nature. It was desired in the first instance to find, as was stated, whether Somatose as measured by its Nitrogen content, was equal as a food to lean beef as measured by its Nitrogen content.

The following are the proportions of Nitrogen contained in materials I employed for feeding purposes :—

	Per cent. of Nitrogen
Oats	2.22
Lean Beef..	3.15
Plasmon	11.16
Somatose...	13.13

Lean beef contains about 68 per cent. of water, whilst Somatose contains 13.26 per cent.

By my analysis I found that 2 grammes of lean beef contained 0.063 gramme of Nitrogen, whilst the same amount of Nitrogen was contained in 0.416 gramme of dry Somatose. The 2 grammes of raw meat contained 1.36 grammes of water, which left a total of solid matter in the 2 grammes of raw beef of 0.64 gramme: the dry Somatose containing 0.063 gramme of Nitrogen amounted to 0.416 gramme, I therefore made up the deficiency in total solid matter between the lean beef and the Somatose by adding 0.224 grammes of Dry Glucose to the Somatose ration.

A third experiment was made by comparing both of these foods with "Plasmon" which is dried casein, as one of the constituents of the ration, in place of lean beef or Somatose. I found that 0.487 gramme of Plasmon contained the same amount of Nitrogen as 2 grammes of lean beef or 0.416 gramme of Somatose, and I therefore weighed out this quantity, but as this left less dry total solid matter than that contained in lean beef, I made up the difference by adding 0.15 gramme of Glucose.

2 grammes of water were mixed with the oats and lean meat, this together with the water contained in the lean beef itself was equivalent to 3.36 grammes of water in the lean beef ration, and this quantity of water was added to the dry ration which contained Somatose, and which contained Plasmon.

Two mice were fed on each of these rations, accurately weighed out, to each mouse every 24 hours, and each mouse was carefully weighed after that time. Some difficulty was found in weighing the mice, as they would not remain still on the pan of the balance; this was overcome by putting each mouse into a small wide mouthed bottle, with a cover of wire gauze to keep it in and weighing the mouse plus the tared bottle and cover.

The weight of each of the six mice was calculated in terms of its original weight, which was taken as 100 parts, and the following graph Fig. 1 shews the changes in weight during each day of 24 hours.

The following were the daily rations for each mouse, numbered 1 to 6.

	MICE.		
	Nos. 1 and 2	Nos. 3 and 4	Nos. 5 and 6
Oats	2.000	2.000	2.000
*Lean meat chopped fine and mixed with the oats	2.000		
*Dry Somatose		.416	
*Dry Plasmon			.487
Dry Glucose		.224	.150
Water	2.000	3.360	3.363
	6.000	6.000	6.000

*The weights of each of these rations contained 0.063 gramme of Nitrogen in addition to the Nitrogen present in the oats. The same amount of dry solid matter and the same amount of water was also contained in each.

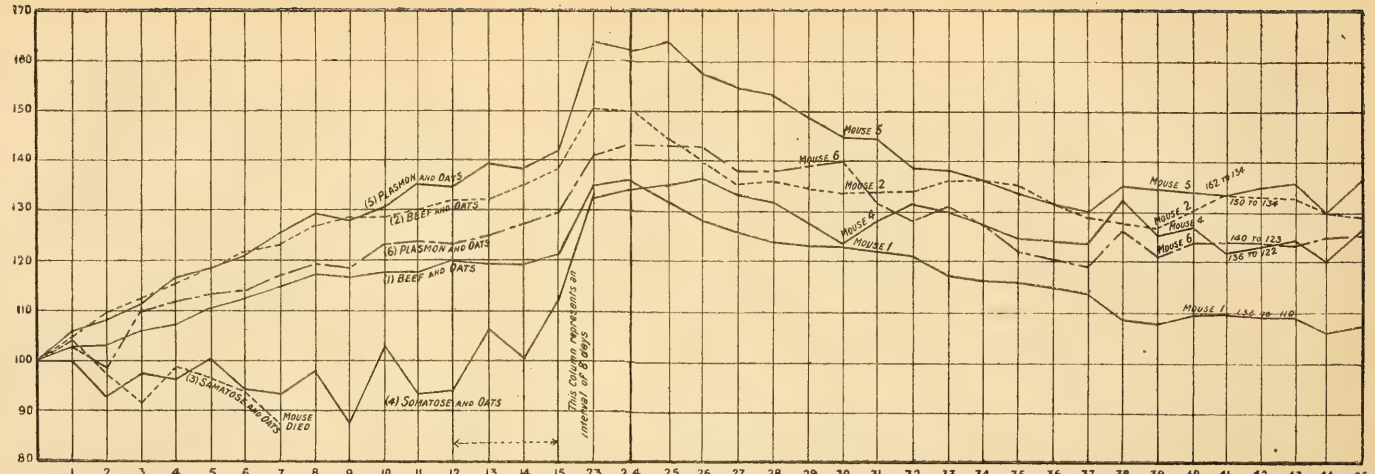

Fig 1.

Rations for the first 12 days weighed in grammes.				Rations changed for 11 days† to
Mice	Nos. 1 & 2	Nos. 3 & 4	Nos. 5 & 6	
Oats	2·00	2·00	2·00	2·64
*Lean beef	2·00	—	—	The extra
*Dry Somatose .	—	·42	—	0·64 was taken
*Dry Plasmon...	—	—	·49	as dry oats
Dry Glucose ...	—	·22	·15	
Water	2·00	3·36	3·36	3·36
	6·00	6·00	6·00	6·00

Rations changed again during 22 days as follows :		
Mice	Nos. 2 & 4	Nos. 1, 5, 6
Oats.....	2·00	2·00
Ordinary Port Wine Residue...	1·00	—
Somatose Port Wine Residue...	—	1·00
Water	3·00	3·00
	6·00	6·00

Actual Weights of Mice in grammes.			
Mice	Rations contained	Before feeding	After feeding for the first 12 days
No. 1	Lean Beef...	13·99	16·76
No. 2	do.	11·00	14·50
No. 3	Somatose ...	10·54	9·23*
No. 4	do.	11·19	10·51
No. 5	Plasmon ...	12·24	16·46
No. 6	do.	12·64	15·59

* Each of these contained 0·063 grm. of Nitrogen. † Daily weighings were not made during 8 days. * On 7th day on which it died.

After the first 24 hours all the mice gained in weight except No. 4 which ate the Somatose ration, and its weight did not change. 100 parts of the other mice became 103 to 106 parts.

After the second day all the mice shewed increase in weight except No. 3 and 4 which ate the Somatose rations and No. 6. No. 3 was three and No. 4 eight parts below their original weight, whilst No. 6, Plasmon fed mouse, also fell to 1½ parts below its original weight.

After the third day the two Somatose fed mice still remained under their original weights, whilst the Plasmon mouse, from being 1½ parts below its original weight became 9½ parts above it, and it and all the others continued with little variations to gain weight during the following 12 days during which the experiment was continued.

The Somatose fed mice remained with great variations below their original weights during the whole of the 12 days, or during the life time of one of them which died on the seventh day at 12½ parts below its original weight. On the 12th day the other Somatose fed mouse was six parts below its original weight and did not appear in good form. It suffered from diarrhœa like the one which died.

The other mice were all above their original weights as follows and were well and happy.

Mice.	Ration.	Gain in parts per 100 of original weight. After 12 days.
No. 1.	Lean beef and Oats	20
,, 6.	Plasmon and Oats	23
,, 2.	Lean beef and Oats	32
,, 5.	Plasmon and Oats	34½

After 12 days the feeding with Somatose, lean beef, and Plasmon was stopped and each mouse was given the same ration, viz:—

Oats	2.71	grammes.
Water	3.29	,,
	6.00	,,

The 2.71 grammes of Oats contained the same amount of solid matter as the 2 grammes of Oats plus the raw beef. The day after this ration was given (the 13th day) the most remarkable result was that No. 4 previously Somatose fed mouse, from being 6 parts below, became 7 parts above its original weight. On the following or 14th day, its weight had fallen to 1 part above its

original weight, on the 15th day it was 11½ parts above, on the 23rd day (after 8 days more, having been fed from the 12th to the 23rd day on oats and water alone) its weight had reached 32½ parts above its original weight.

The following shows the increase in each of the mice after 23 days:—i.e. After feeding with special foods including Lean beef, Plasmon, and Somatose for 12 days changed to oats and water for the succeeding 11 days.

	Increase above the original weight taken as 100.
No. 5 Mouse previously fed with Plasmon, Oats, and Glucose... ...	64
No. 2 Mouse previously fed with Beef and Oats	50½
No. 6 Mouse previously fed with Plasmon, Oats, and Glucose... ...	40½
No. 1 Mouse previously fed with Lean beef and Oats	35
No. 4 Mouse previously fed with Somatose, Oats, and Glucose. ...	32½

On the 23rd day a fresh series of experiments was started with the same mice, which were all much above their original weights.

0.71 gramme of the Oats was removed, and for it substituted 1 gramme (a) of the residue obtained by evaporating Port Wine to dryness, which contained Somatose equivalent in Nitrogen content to 7 per cent. of Lean beef, and (b) of the residue obtained by evaporating ordinary Port Wine to dryness.

	Percentages.		
The Wines consisted of:	Somatose Port Wine.		Ordinary Port Wine.
Alcohol and water	87.64	...	88.66
*Total dry solid residue...	12.36	...	11.34
	100.00		100.00
* Containing Nitrogen	0.221	...	.02

0.221 Nitrogen is equal to 1.69 Somatose and 7·0 of lean beef. These wines contained about 9 per cent. of sugar.

The three mice, No. 1, No. 5, and No. 6, had the Somatose wine residue, and No. 2 and No. 4 the ordinary Port Wine residue ration, and this series was continued for 19 days more, that is, till the 42nd day of the experiment.

During this regime they all lost weight and on the 42nd day the following were the weights below the original weights taken the first time the mice were weighed:

		Parts decrease (original weight taken as 100) between the 23rd and the 42nd days.
Somatose Wine Residue and Oats fed mice	No. 1.	26.13
	,, 5.	28.52
	,, 6.	17.49
Ordinary Wine Residue and Oats fed Mice	No. 2.	15.84
	,, 4.	11.31

These figures shew that the average loss of weight in the three mice fed with Somatose Port Wine Residue and Oats, between the 24th and 42nd days was 24.71 parts per 100 of the original weights of the mice, whilst the average loss of weight in the two mice fed with Ordinary Port Wine Residue and Oats, during the same time was 13.57 parts per 100 of the original weights.

The Port Wine Residue was therefore not equal to the Oats as a feeding material, whilst the Port Wine Residue containing the Somatose, which was advertised as a wonderful feeding material, proved much less valuable as a food than the residue obtained from ordinary port wine.

Another series of experiments was made by feeding two mice each with rations per 24 hours of:—

"A" Oats — 3 grammes, with 1 gramme of Glucose.
"B" Oats — 3 grammes, with 1 gramme of Port Wine Residue
"C" Oats — 3 grammes, with 1 gramme of Somatose Port Wine Residue — Water in each 2.5 grammes.

The average weights for the two mice in each experiment shewed that, with "A" and "B" rations which were Oats, mixed respectively with Glucose and with Ordinary Port Wine Residue, the weights increased during the first 24 hours, with Port Wine Residue and Oats to $4\frac{1}{4}$ parts above the original weights taken at 100, with Glucose and Oats, to 2 parts per 100 above the original weight of mice, whilst in "C" with the Somatose Port Wine Residue, mixed with Oats, both mice lost weight on the average to 4 parts per 100 of original weight of mice.

On the second day the weights *gained* by "A" was $8\frac{1}{2}$ and by "B" $8\frac{3}{4}$ parts, whilst with "C," although they had gained weight from the previous day, they were still $1\frac{1}{4}$ parts below their original weights. These experiments were commenced on a Thursday at

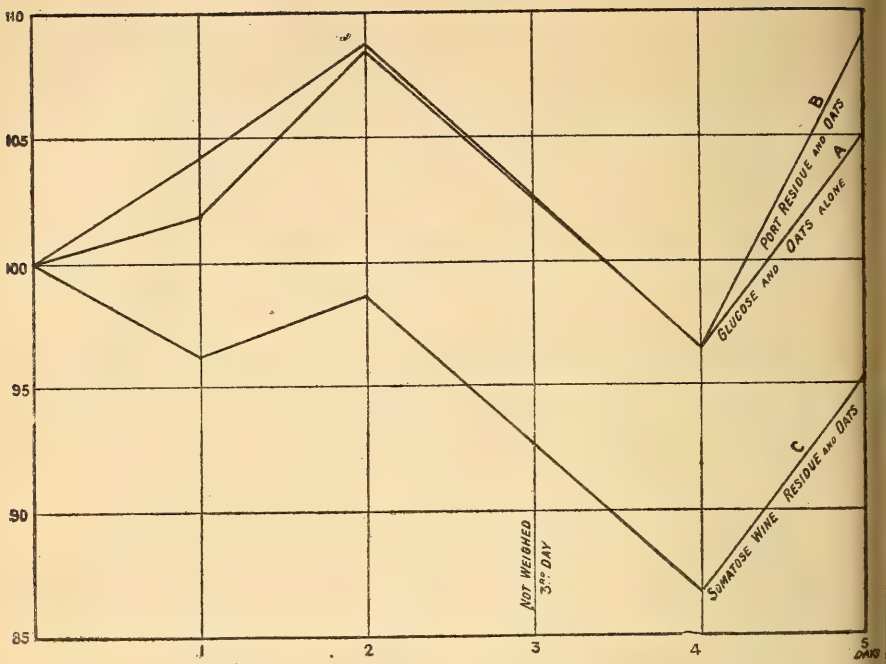

Fig 2.

This graph shows the *average* daily weights of two mice in terms of their original weights taken as 100, each two fed on the following daily rations :

	Mice A		Mice B		Mice C
	grammes		grammes		grammes
Oats	3·0	...	3·0	...	3·0
Glucose	1·0	...	—	...	—
Ordinary Port Wine Residue	—	...	1·0	...	—
Somatose Port Wine Residue	—	...	—	...	1·0
Water	2·5	...	2·5	...	2·5
	6·5		6·5		6·5

The six mice each received at the beginning of the second day double rations (to last from Saturday till Monday). They evidently ate both during the first day or so and starved and lost weight during the second day. The same daily rations on the fourth day considerably increased their weights on the fifth day. It will be seen that those which ate the rations containing somatose lost weight from the first.

noon, and as the end of the second day was Saturday at noon, we decided to leave them with double rations, till Monday at noon, for two consecutive days, thus, on the fourth day the mice "A" and "B" from being about 8½ parts per 100 above, had fallen to 4 parts below their original weights, whilst the "C" mice with Somatose Wine residue rations fell by 13 parts per 100 of their original weights. The mice had evidently eaten all the two days' rations on the first day, and starved during the second. It is remarkable that mice are capable of eating from half to a whole of their own weight of food per day.

On the fifth day the "B" mice, fed with ordinary Port Wine residue rations were 9 parts above their original weight. The "A" which had Glucose in their rations were 5 parts above their original weight, and the "C" series, which had Somatose Wine Residue were 4½ parts *below* their original weights,

I made another set of experiments, to find how the mice would fare if fed on the rations given in my first series of experiments, but in one series simply leaving out the Somatose without adding anything in its place. Two mice were fed therefore with Oats 2 grammes. Plasmon 0.487 gramme. Glucose 0.15 gramme. Water 3.36 grammes—Total 6 grammes, against other two mice fed with Oats 2 grammes. Glucose 0.224 gramme. Water 3.36 grammes —Total 5.584 grammes, this being the same as the ration mixture of my first experiments, but with the Somatose left out.

The mice fed on the first named or Plasmon ration, each gained weight during the *first* day, one mouse 7½, and the other, 9 parts above their original weights taken as 100. The other two mice fed with a decreased weight of food corresponding to the weight of Somatose in the ration of my first experiments, each lost weight, the first to 1½ and the other to 3½ parts per 100 of mouse.

At the end of the second day the two mice fed with Plasmon in their rations were respectively 11½ and 15½ parts above their original weights, whilst the other two with decreased rations were, the one ⅓ part below, and the other two parts above their original weights.

At the end of the third day the first two mice fed with Plasmon in their rations were respectively 18 and 18½ parts above, and the other two mice fed with decreased rations, were 1, and 2¾ parts respectively per 100 above the original weight.

At the end of the fourth day the first two with Plasmon in their rations were respectively 23 and 24 parts above, and the other two without Plasmon were respectively 3 above, and 1½ parts below their original weights. This series proved that whilst the Somatose fed mice in my first 12 days' experiment remained practically below

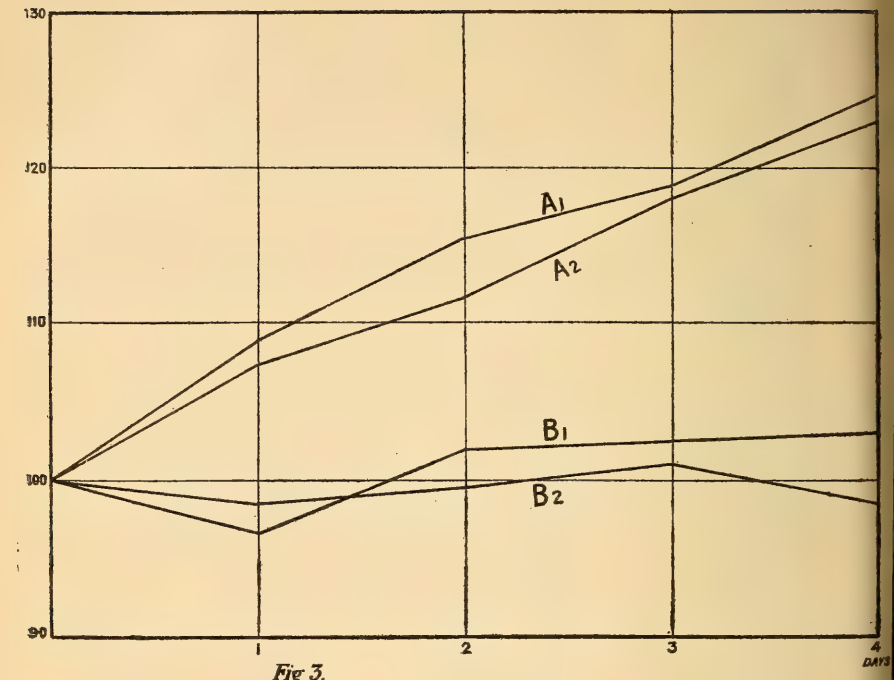

Fig 3.

This graph shows the weight results obtained by feeding two mice A 1 & 2 and B 1 & 2 with daily rations as follows:

		Grammes.		
		A 1 & 2		B 1 & 2
Oats	2·00	...	...	2·00
Plasmon	·49	...	none (·42 somatose omitted)	
Glucose	·15	...	...	·22
Water	3·36	...	...	3·36
		6·00	...	5·58

These experiments were made to find whether mice B 1 & 2 would thrive better without somatose, the other constituents of the ration shown in graph Fig. 1 being left in; for comparison the ration given to mice A 1 & 2 were as shown in graph Fig. 1 (mice 5 & 6). The nitrogen content of ·49 gram. of Plasmon being the same as ·416 gram. of somatose which was left out or of 2 grams. of lean raw beef.

These results show that the food value of somatose was less than nothing as the mice thrived better without it.

their original weights during 12 days with very great variations below, the mice in this series simply with the Somatose omitted remained at or above their original weights with very little variation, the rations being sufficient to keep them in good health.

These figures shew therefore, first, that Somatose is certainly not a food, and second, that it is not even a neutral body, so far as its food value is concerned, but is really an irritant, causing gastric disturbance and diarrhoea and yet this is the German super-food intended to increase the weight and body capacity of English people and especially invalids, at 25/4 per lb.

I should have liked to try the effect of mixing Liebig's Extract in Nitrogen equivalent in place of Somatose as a food, I believe it would have proved beneficial instead of acting as a poison like Somatose, but I learned that, to feed mice with any kind of food and weigh them, was in contravention of the Vivisection Act, and I therefore went no further.

Before I became possessed of this knowledge I had made some experiments which it might be interesting to record as others, who can obtain the necessary permission from the Home Secretary, might follow them up.

In this series of experiments I wished to find what effect on the feeding of mice different starches would have when mixed with Oats. I consequently took one heavy and one lighter mouse, and fed each with 1 gramme of different raw starches mixed with 3 grammes of Oats and $3\frac{1}{2}$ grammes of water. The starches used were:—

Maize.
Potato.
Rice.
Sago.
Tapioca.
Wheat.

The feeding with the above daily rations was continued for 17 days and the results are given briefly as follows:—

1. Maize. The original weights of the two mice were 87.2 and 20.1 gramme respectively. They both remained about the same weight throughout the 15 days, but were a little above the original weights.

2. Potato Starch. The original weights were 79 and 12 grammes respectively. Both gained weight slightly during the first nine days, on the 10th, 11th, 12th, and 13th days they both gradually lost weight, and both died on the 13th day. They then weighed 76 and 9 grammes respectively.

3. Rice. Original weights of mice 87 and 20 grammes respectively. Each had gained after 15 days about half a gramme in weight.

4. Sago. The original weights of the mice were 88 and 21 grammes respectively and they both gained weight after 15 days. They weighed 91 and 24 grammes respectively.

5. Tapioca. The original weights of the mice were 91 and 24 respectively. They remained about the same weight throughout, weighing after 15 days $90\frac{1}{3}$ and $23\frac{1}{3}$ grammes respectively.

6. Wheat. The original weights were 89 and 22 grammes respectively. They remained about the same weight throughout.

It was remarkable that the excrements of the mice fed with rations containing Potato and Sago, contained large quantities of starch granules intact with some slightly affected, and they were large and white as compared with the normal excrement. Those from the Maize and Tapioca fed mice, shewed a small quantity of the granules of the starches intact, whilst the mice seemed to have digested completely the rice and wheat starches.

[*From Volume 62, Part II, of* "MEMOIRS AND PROCEEDINGS OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY," *Session, 1917-1918.*]

The Fossil Foraminifera of the Blue Marl of the Côte des Basques, Biarritz

BY

EDWARD HALKYARD, F.R.M.S.

EDITED WITH ADDITIONS BY

EDWARD HERON-ALLEN, F.L.S., F.G.S., F.R.M.S.

AND

ARTHUR EARLAND, F.R.M.S.

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INTRODUCTION BY THE EDITORS.

Edward Halkyard, who died on the 19th June, 1917, in the 64th year of his age, was probably little known, personally, to his contemporary workers upon the Protozoa as, owing to poor health and a retiring disposition, he mixed very little in zoological circles. He was, however, a keen student of the Foraminifera and carried on an extensive correspondence with other workers in the same field of research. Earland became personally acquainted with him at some time between 1885 and 1888, through meeting him at the Royal Microscopical Society, of which Halkyard was a Fellow, and subsequently corresponded with him for several years. He was at that time working out the Foraminifera of the Channel Islands and during the years 1887—1890 Earland made numerous gatherings and collections in Jersey, with the view of furnishing material to Halkyard, who was particularly anxious to rediscover *Haliphysema tumanowiczii*, Bowerbank, which had been recorded by Savile Kent from that island in 1878, but had since then escaped the notice of Halkyard and other naturalists. The species was eventually rediscovered in abundance in the St. Ouen's Bay area, but too late for inclusion in Halkyard's paper "Recent Foraminifera of Jersey" which was published by the Manchester Microscopical Society in 1889. A record of the discovery, however, appears in his subsequent paper "A Comparative List of the Recent Foraminifera of the Islands of Guernsey, Herm and Jersey" published by the same Society in 1891. These two papers possess a value to students of the group out of all proportion to their modest size, and to this day constitute the sum of our knowledge of the Foraminifera of the Channel Islands. A third paper "Plans of Growth and Form in the Foraminifera" published by the Manchester Microscopical Society in 1893 concluded his contributions, published in his life-time, to the literature of the Foraminifera.

About this time he became interested in the Eocene Marls of Biarritz, as his paper shows that he first became acquainted with the locality in the spring of 1893. Between that date and 1902 he appears to have made several visits for the purpose of collecting material. A letter from Halkyard to Heron-Allen dated 1st October, 1894, lies before us in which he tells us that the principal collection was made in November, 1893. In this

letter he observes: "The Marls are of great thickness and, as far as I can learn, are not divisible into Zones, though I see already that there is a change in the Foraminiferal fauna between the highest and lowest portions of the beds. I have therefore taken samples at fairly equal distances apart, and shall work these out first, and then I may know better how, really, to commence the work. I wish I could get some Geologist to visit Biarritz with me at some future time, so that I might benefit by his knowledge. Whilst down there last November I made enquiries, but could not hear of any local Geologist to whom I could apply and I find that works on these strata are rare . . . . . Neither is there a geological map of the district published yet, so I begin to think I have an uncommonly tough job before me, but I console myself with the thought that at least I shall get many fine specimens for my cabinet, and am bound to add to my own knowledge, if not to some one else's."

Halkyard would appear to have been unacquainted with the works (up to that date) of which we have given a list on page 133, but nevertheless this work which it has been our labour for the past two years to edit and to supplement, affords proof that his tussle with the "tough job" was productive of one of the most important contributions to the literature of the Eocene Foraminifera.

From this time, however, Halkyard appears to have become to some extent a scientific recluse. His correspondence with us gradually ceased, and nothing being published under his name, we were not even certain whether he was alive or dead.

In 1915, Heron-Allen was in Manchester, representing our late friend, Edward Minchin, F.R.S., who was President of Section D. in the Meeting of the British Association of that year. At Professor S. J. Hickson's request he examined and rearranged Halkyard's collection of Foraminifera in the Manchester Museum, among which he found a large number of specimens from Biarritz. It then transpired that these had been given to the Museum some years previously by Halkyard, together with his library and all his MSS, notes, and drawings. The MSS were placed in our hands for examination and we recognised at once that they were of great importance and ought to be edited and published. Having reported our views to Professor Hickson he succeeded in getting into touch with Halkyard, then living at Alderley Edge. Owing to the state of his health, the author did not feel himself equal to the labour of completing his monograph but, in a letter dated 21st August,

1916, he expressed his pleasure at learning that we were willing to revise and prepare his MSS. for publication.

The war and pressure of other engagements still further postponed publication and in the interval Halkyard has died. The publication of his notes and the completion of his work therefore may be regarded as a heart-felt tribute to the memory of an old and esteemed correspondent.

The long interval which has elapsed since Halkyard wrote the existing draft of his MS. has rendered many alterations in his nomenclature necessary. It is not easy to understand why he should have ceased his labours when they were so near completion. We know that he was in active correspondence with Frederick Chapman, and the late Fortescue W. Millett, and if he felt himself unable to complete the task he might have sought assistance and collaboration, instead of giving his MSS, drawings, and specimens, to the Museum where, had Professor Hickson not kept them in mind and aroused the interest of Heron-Allen in 1915, they might easily have remained unnoticed until their scientific value had been lost. The plates have been prepared with all Halkyard's skill, and he was a fine draughtsman, and although the MS was far from ready for publication, being more or less in the shape of a rough draft, and imperfectly arranged, it was in such a condition that a few weeks of additional work would have sufficed for him to complete the long task, and saved us the many months which we have found necessary to pick up the scattered and unfamiliar threads. Besides the congenial labour of editing Halkyard's draft, we have examined a considerable quantity of his untouched material, which has resulted in the addition of some thirty-three species to his list as he left it. Even as now published we are conscious of many shortcomings, especially in the synonymies and the arrangement of species, but to have set these in the accepted order would have necessitated the rewriting of the entire paper. As it is, there are a few of Halkyard's species which we have been unable to trace at all. The specimens have disappeared from the type slides and cannot be found. Whether they have become lost, or whether he altered the name of the specimen without destroying his original notes, we cannot say. This theory appears very possible as there are many instances in which he changed his views on the identity of his specimens during the preparation of his MS. Perhaps this feeling of indecision as to the identity of specimens may have been responsible for Halkyard's abandonment of his work. Judging from some of his notes and correspondence he seems to have gradually lost all sense of the close affinity of rhizo-

podal species and to have aimed at, or even required, an absolute identification of his specimens with the published drawings of recorded species. This has resulted in a great multiplication of specific names in certain genera of the Lagenidæ, a course of which we do not approve as will be seen by our notes. The long delay in publication has furthermore robbed Halkyard of the authorship of many interesting forms which he found at Biarritz, but which have, in the interval, been described and figured from various localities by other authors. Six of his most interesting species will be found to have been anticipated by ourselves in our Monograph on the Foraminifera of Selsey Bill published in 1908-9, the Eocene deposits of the Bill being of similar age to those of Biarritz. Again, Liebus in 1911 figured and described, as will be seen, another of Halkyard's most interesting species. (See No. 321.)

There are many points in Halkyard's paper with which we feel bound to disagree, and it is probable that if he had continued to work at the subject he would himself have modified his paper in many directions. As an example of this we may mention his views on the sub-genus Siphogenerina, Schlumberger, which later research has proved to be an artificial distinction. But we have adhered to the principle of printing his MS in full, confining ourselves as a rule to a supplemental note in round brackets in which we record our opinion on Halkyard's specimens, all of which were carefully examined by us and compared with his notes and the figures of the authors referred to. In the case of some 27 species we have found it impossible to accept Halkyard's identification at all, and the name which we propose to substitute is in these cases shown above Halkyard's and enclosed in square brackets.

We should have been justified in changing the name in many cases where we have not done so, but we have confined ourselves to an expression of dissent in the supplementary note. We have also added the 33 species which we have found either in Halkyard's unexamined material, or, in some cases, on slides labelled with the names of other species. These additional forms are also distinguished by square brackets, and, as a rule, without any comment as to distribution, &c., as we were not in the position to give such information, owing to the nature and extent of the material submitted to us.

In conclusion we must mention a paper published in 1906 by Dr. Adalbert Liebus.* It is clear that Halkyard was in com-

* A. Liebus, Uber die Foraminiferenfauna der Tertiärschichten von Biarritz. Jahrb. d.k.k. geolog. Reichsanst. Wien. 1906. Vol. LVI. Pt. 2, pp. 351-366. Pl. IX. and 8 figs. in text.

munication with Liebus, and supplied him not only with material, but with notes and drawings, but we have found no trace of the correspondence among the Halkyard papers. Liebus admits his indebtedness to Halkyard for the material and topographical information, and figures several unimportant species, but gives, with perhaps one exception, no indication of any of Halkyard's new species. He gives a list of 125 species, 66 of which are not recorded by Halkyard, whilst Halkyard's paper records 288 species not recorded by Liebus. In our opinion Liebus' paper is of no importance in the light of the publication of the present monograph.

We have combined Halkyard's record of species and our own, for purposes of reference, in an Alphabetical Index of Genera and species to which the systematist is referred as an essential part of the present publication. The plan is an unsatisfactory one from many aspects, but it was the only way in which we could place before the student of the Foraminifera the combined results of Halkyard's work and our own, as a complete record of the species identified by him and by us in the material at our command.

H-A. & E.

BIOGRAPHICAL NOTICE OF THE LATE EDWARD HALKYARD.

We are indebted to the author's brother, Mr. W. R. Halkyard, for the following particulars.

"Edward Halkyard was the second son and fourth child of the late Henry Halkyard, F.R.C.S., of Hope House, Oldham, Lancashire, and was born May 7th, 1854.

"The Halkyard family has been continuously connected with the medical profession in Oldham for a period approaching two hundred years, and, in fact, a member of the family, but on the distaff side, is a prominent practitioner in the town at the present time. He was educated at a private school conducted by the late Reverend H. M. Keywood, at Beechfield, Alderley Edge, but at the age of 16, he was attacked by the serious malady which, more or less, dogged the whole of his subsequent life, and had to leave school.

"He made an effort to become an engineer, and thus acquired some skill as a draughtsman, but, his health continuing unsatisfactory, he went in 1874 on a sailing vessel to Australia; returning home, however, by the same ship almost immediately. This voyage seemed to have been attended with good results for a time, but, soon after his return, the old trouble reasserted itself, and in 1876 he again went to the Antipodes and this time he remained in Melbourne, but chiefly in Hobart Town, Tasmania, for some five years, returning home in 1881 at the request of his father, who was in failing health.

"Whilst in Australia he was for some time in the Government service.

"On his return home a second time he tried to resume his work as an engineer with a well-known Manchester firm, but his old enemy once again asserted itself and he was compelled to give up this work.

"After this he never again attempted to follow any business or profession, but he was a man to whom an idle life was impossible, and largely, no doubt, to occupy his time, he entered upon the study of the subjects upon which you are good enough to say he became an established authority.

"For many years for reasons of health he found it inadvisable if not impossible to winter in the north of England, and so it became his custom to spend this part of the year further south —sometimes in the south of England or Channel Islands, and at others in the south of Europe, and it was his habit to make use of his opportunities then and there to collect specimens and take dredgings which, upon his return home, he submitted to diligent and careful microscopical examination with the results of which you are acquainted.

"This habit of life continued for a number of years, and until his physical powers, and more particularly his eye-sight, gradually began to fail, and rendered further work impossible.

"When he gave it up he presented his specimens to the Victoria University, Manchester, where they are now placed in the Museum.

"He was a quiet, unassuming, generous-hearted English gentleman of the highest principles, to which he was always true, and with a keen sense of his duty to his fellow men. From a sense of this duty he never married, and he passed quietly, even as he had lived, to his rest at Alderley Edge on the 19th June, 1917."

To this we may add from our personal knowledge of the man, that he was a fine example of that patient and unostentatious body of amateur scientists, who, devoting their lives to the study of highly specialised branches of research, have contributed so greatly to the scientific knowledge of the world. Such men were—in his own branch of science—Dr. H. B. Brady, the Reverend A. M. Norman, and Fortescue W. Millett, to name but these, men who, undisturbed by the exigencies of Professorial life, have been able to devote themselves to the fascinating drudgery of Systematic Zoology, and upon whose labours the professional scientist is compelled to rely, whilst absorbed in the wider problems of Biological Research.

H-A. & E.

INDEX

Of species recorded by the Author, and of species subsequently added or referred to in the notes by the Editors.

No apology will be considered necessary for the following Index, when it is observed that it contains the names of over 460 species as against the 345 recorded by the author. The re-assignment of many species to different Genera in the light of later discoveries and the presence in the material of many forms which escaped Halkyard's diligent researches, or which appear to be nearer to the forms he has described, has rendered it necessary to add this Index for the purpose of facilitating reference to his own work and ours as a whole.

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THE FOSSIL FORAMINIFERA OF THE BLUE MARL, CÔTE DES BASQUES, BIARRITZ.

The Blue Marl of Biarritz forms a cliff stretching for nearly three-quarters of a mile in a direction from N.N.E. to S.S.W., and above the Bathing Establishment at its northern extremity where it abuts on the promontory of La Talaye it attains a height of about 135 feet. This height is maintained for about two thirds of its length, when it commences to decrease in altitude finally dying away at the valley of Chabiague to the south. At the northern section where the cliff is most precipitous, and until a short distance past the Villa Notre Dame, the beds are inclined at an angle of about 40°, dipping towards the north. This angle afterwards gradually decreases and at the villa called l'Ermitage is from 10° to 15° only. At l'Ermitage a hollow in the upper part of the cliff is filled with red and yellow sands and gravels. In the upper part of the Marl hard layers are few and thin, these beds are wanting in the middle portion of the marl and are replaced by sparsely distributed large concretionary nodules of hardened marl of a light grey colour, tinged brown where weathered, a colouration no doubt due to iron oxide. In the southern section, commencing south of l'Ermitage, hard beds of limestone are numerous, and the marl itself, except at the extreme base of the cliff is more sandy. In some portions these hard beds are almost horizontal.

The strata above described have been placed by geologists in the Middle Eocene series, and are believed to be contemporary with the Bartonian beds of England. They are referred to as the Orbitoidal or *Serpula spirulæa* Marls.

Having written thus briefly of the physical features of the region of the Blue Marls I will now deal with their micro-zoological contents. The collection of Foraminifera which is about to be described was obtained at three different times. In the spring of 1893 a sample of marl having been taken with a view to a search for Foraminifera, the results were so encouraging that a further examination was decided upon. A second visit was made to Biarritz in the autumn of the same year, and a systematic series of gatherings taken. It was at first thought

that it would be possible to learn from these gatherings something of the relative predominance or scarcity of the different species at the different parts of the beds, but a third series of samples taken in an irregular manner in 1897 and 1902 showed that any deductions arrived at from the 1893 collections as to the distribution of species throughout the whole extent of the strata would be unreliable. These reasons, as well as the great thickness of these beds of Blue Marl and the lack of marked horizons in them, have led me simply to describe the Foraminifera collected as coming from the Blue Marl as a whole, though occasionally I may find it convenient to make a reference to the upper or lower beds as the undoubted provenance of a species.

In order to show in a fuller manner the microzoic contents of the marl it will be well to give notes of washings obtained from nine samples of marl taken in November, 1893. These notes will give a good idea of the nature of the material dealt with. Before proceeding further I may say that not only were samples taken of the soft beds, but also hand-specimens of the hard limestones containing numerous specimens of Nummulites and Orbitoides. Any species found in these hard samples will be referred to as having been so found.

GATHERINGS, AUTUMN, 1893.

Sample No. 1.—1 lb. of marl taken from near top of Cliff on ascending zig-zag footpath behind the Bathing Establishment. Marl light-coloured even when wet. Residue left after washing weighed 60 grains and consisted of Quartz-sand, fragments of Molluscan shells, Polyzoa, Echinoderm spines, Ostracoda, and Foraminifera, as well as casts in pyrites of small Molluscan shells and Foraminifera. *Miliolina*, plentiful and well preserved. *Cristellaria*, plentiful but rather broken. *Operculina*, frequent and much broken. Specimens often stained with iron oxide.

Sample No. 2.—1 lb. of marl from half-way up the Cliff near the end of the sea-wall. This sample was taken from a block which had fallen on to the road under the cliff, otherwise a sample from this place could not have been obtained, the cliff being much too precipitous to be climbed. The residue left after washing this sample weighed 300 grains and consisted of coarse and fine sand, Foraminifera, Polyzoa, fragments of Molluscan shells, Echinoderm spines, Ostracoda, and Sponge-spicules. The most conspicuous Foraminifera were much worn and decomposed specimens of *Operculina complanata*, *Cristellariæ*, *Textularia trochus*, and *Tritaxia ulmensis*.

Sample No. 3.—1 lb. of marl from top of Cliff to south of large new villa (Villa Heeren) above end of sea-wall. Residue left after washing weighed 342 grains and consisted of sand, Foraminifera, small Molluscan shells and fragments of larger ones, Polyzoa, Echinoderm spines, Ostracoda, and a few small Fish-teeth. Pyrites frequent in this sample, many of the Foraminifera being filled with the same.

Sample No. 4.—1 lb. of marl from base of Cliff 120 yards south of last gathering. The residue left after washing weighed 43 grains and consisted of sand, Foraminifera, Polyzoa (plentiful), fragments of Molluscan shells, also casts of same in clay, Ostracoda, small Fish-teeth (very rare). The siftings (fine enough to pass through a sieve of 80 meshes to the inch) consisted almost entirely of Foraminifera. Altogether the washings from this sample were coarser than those from No. 3, and were much richer in Foraminifera though the total weight was so small.

Sample No. 5.—1 lb. of marl from base of Cliff about 100 yards north of small rivulet descending from Villa Notre Dame. Total weight of residue 188 grains, composed of sand, fragments of Molluscan shells, Foraminifera, Polyzoa, Ostracoda, Echinus-spines, tubes of Serpula, fragments of small Crinoids, and Sponge-spicules. Arenaceous forms of Foraminifera were more common than in any previous sample, and many of the specimens are filled with calcite, whilst some genera, notably *Miliolina*, *Biloculina*, and other porcellanous forms are almost entirely represented by casts in this mineral, the small portions of shell-wall remaining being of a chalky consistency.

Sample No. 6.—1 lb. of marl gathered 10 feet above base of Cliff on north side of rivulet descending from Villa Notre Dame. Residue after washing weighed 35 grains and contained much mica in finely comminuted state. The organic contents were Foraminifera, spines and fragments of tests of Echinoderms, Polyzoa, Ostracoda, and large Sponge-spicules.

Sample No. 7.—1 lb. of marl from base of Cliff 30 yards north of last ravine before coming to l'Ermitage. Weight of residue after washing was 160 grains and consisted of sand, Foraminifera, Polyzoa, joints of Crinoid-stems, fragments of Echinus-tests and spines, fragments of Molluscan shells, Ostracoda, and a few small Fish-vertebræ. Calcite casts of Foraminifera were frequent

Sample No. 8.—1 lb. of very sandy marl from 15 feet above the base of the Cliff below l'Ermitage, but slightly to the north of the same. Residue after washing weighed 713 grains

and consisted of much quartz sand, grains of glauconite, Foraminifera, Polyzoa, Ostracoda (very rare), Echinoderm remains, Sponge-spicules, fragments of Molluscan shells and sand-casts of the same. Casts of Foraminifera occur in pyrites, calcite, and glauconite.

Sample No. 9.—1 lb. of sandy marl from base of Cliff about 150 yards south of l'Ermitage. Residue (which was fine) after washing weighed 420 grains, and consisted of sand, Foraminifera, Ostracoda, spines and fragments of tests of Echinus, fragments of Molluscan shells, with very rarely Crustacean remains, plates of Synapta, and a few spicules of Alcyonidæ or Gorgonidæ.

The residues spoken of above were such as would pass through a sieve of twenty meshes to the inch.

From the above analysis it will be seen that generally speaking the Blue Marl is of similar character throughout a large portion of its great thickness, though it does vary slightly in different parts; thus Sample No. 1 was very light-coloured and was easily seen to contain iron oxide in appreciable quantity. Sample No. 6 was notable for its micaceous constituent, while in Sample No. 8 glauconite was conspicuous.

The gatherings taken in April, 1897, were chiefly from the marl beds in the neighbourhood of the end of the sea-wall, between tide-marks, and particular attention was paid to the search for sandy "pockets," which were found to be very rich in the larger forms. One "pocket" of a few inches square and an inch or so in depth was found to contain over fifty specimens of *Orbitoides tenuicostata*, Gümbel, besides numerous other species. At the same time search was made for large conspicuous isolated specimens, and many fine *Nodosariæ* were obtained. Those of 1902 were partly from the end of the sea-wall and partly from top of Cliff 100 yards S. of l'Ermitage.

As regards the fact noted that in Sample No. 5, 1893, the porcellanous species were mostly represented by casts, it will be as well to refer here to the experiments made by Cornish & Kendall* as to the relative stability, or resistance to solubility in presence of carbonated water, of porcellanous and vitreous Foraminifera, the former presumably being composed of carbonate of lime in the form of aragonite and the latter of the same substance in the form of calcite. The authors show that the stability of aragonite is much inferior to that of

* On the Mineralogical Constitution of Calcareous Organisms, Geol. Mag., Dec. III., Vol. V., No. 2., 1888, pp. 66—73.

calcite, and is probably due to structural differences. For fuller information I must refer my readers to the original paper.

To the best of my information very little has been written of the Foraminifera of the Blue Marl, and only the larger forms are recorded. Philippe de la Harpe has written five papers on the Nummulites of Biarritz which were published in the "Bulletin de la Société de Borda á Dax" during the years 1879 to 1881. Eighteen species are noted in those works, of which number six were found in the Blue Marl of the Côte des Basques. My search has been rewarded by nine (?) species, five of which do not appear in M. de la Harpe's list. In 1873 M. le Comte R. de Bouillé published at Pau a work entitled "Paléontologie de Biarritz et de quelques autres localités des Basses-Pyrénées." In the list of fossils in this work are mentioned as being found in the Blue Marl two species of *Operculina*, five of *Orbitoides*, and three of *Nummulites*. (We have reproduced Halkyard's notes on this work in Appendix A. H-A. & E.) In Prof. T. Rupert Jones' "Catalogue of the Fossil Foraminifera in the Collection of the British Museum" there is mention made of many specimens of *Nummulites*, *Orbitoides*, and *Operculina* from Biarritz, some of which are marked "Middle Beds", and others though not so marked are evidently from the lower hard beds of the same series. These "Middle Beds" are the ones now under consideration.

The works by the above-mentioned authors are the only ones of any importance which I have come across dealing in any way with the Foraminifera of Biarritz. (See, however, our Introductory Observations, H-A. & E.)

Before proceeding to describe the species of Foraminifera in my collections, I desire to take this opportunity of recording my indebtedness to Mr. F. Chapman, A.L.S., F.R.M.S., to whom my best thanks are due for his kind assistance in the determination of critical species. I also have to thank Mr. F. W. Millett for his ready response to my appeals for his help.

In order to avoid an unnecessary addition to the length of this paper, I have only given two references to figures of each species described, viz., one to the original figure and description, and the other (where possible) to that given by the late Dr. H. B. Brady in his magnificent work on the Foraminifera collected during the Challenger Expedition, which work I believe the most generally accessible to all students of the Foraminifera.

DESCRIPTION OF GENERA AND SPECIES.

SUB-KINGDOM: PROTOZOA.

CLASS: RHIZOPODA.

ORDER: FORAMINIFERA.

FAMILY: MILIOLIDÆ.

SUB-FAMILY: NUBECULARINÆ.

GENUS NUBECULARIA Defrance.

1. NUBECULARIA DIVARICATA, Brady.

Sagrina divaricata, Brady, 1879, Quart. Jour. Micro. Sci., vol. XIX, N.S., p. 276, pl. VIII, figs. 22-24.
Nubecularia divaricata, Brady, Chall. Rep. 1884, p. 136, pl. LXXVI, figs. 11-15.

A few single chambers of this species were found in the upper portion of the Marl, the great majority being collected almost at the summit of the northern part of the Cliff behind the Bathing Establishment.

(The specimens are all fragmentary, the characteristic aperture, however, renders their identification certain).

SUB-FAMILY: MILIOLININÆ.

GENUS BILOCULINA, d'Orbigny.

2. BILOCULINA RINGENS, (Lamarck).

Miliolites ringens, Lamarck, Ann. Mus. 1804, 351, No. 1.
Biloculina ringens, d'Orbigny, Ann. Sci. Nat. VII, 1826, p. 297, No. 2.
B. ringens, Brady, 1884, Chall. Rep., p. 142, pl. II, figs. 7, 8.

The specimens are small and sometimes only represented by casts and are by no means numerous. Generally speaking the species seems to be confined to the upper half of the marl-beds.

(The few specimens in the collection in perfect condition are from Gathering 3 and of the type figured by Brady in the Challenger Report, *ut supra*.)

3. BILOCULINA ANTIQUA, Karrer.

Biloculina antiqua, Karrer, 1867, Sitz. k. Ak. Wiss. Wien, LV, (1), p. 365, pl. III, fig. 7.

This variety of *B. ringens* differs from the type in having the breadth of the chambers greater than the length. In extreme cases the chambers are twice as broad as long. Only five specimens were collected at Biarritz, and these are in the form of casts in calcite or pyrites.

(All the specimens being casts, it is not easy to state absolutely what the external appearance of the original shell was. Karrer's species is hardly separable from *B. ringens*. The Biarritz specimens which are more suggestive of *B. depressa* were probably even broader than Karrer's figure, but even so seem hardly worth recording as a separate species).

4. Biloculina depressa, d'Orbigny.

Biloculina depressa, d'Orbigny, 1826, Ann. Sci. Nat. VII, p. 298, No. 7.
B. depressa, Brady, 1884, Chall. Rep., p. 145, pl. II, figs. 12, 15-17, and pl. III, figs. 1, 2.

Rare, and generally badly preserved, usually occurring in the form of calcite casts with a small portion of the original shell-wall adhering thereto.

(The majority of the specimens though merely casts are identifiable with certainty owing to their shape.)

Genus Spiroloculina, d'Orbigny.

5. Spiroloculina excavata, d'Orbigny.

Spiroloculina excavata, d'Orbigny, 1846, Foram, Foss. Vienne, p. 271, pl. XVI, figs. 19-21.
S. excavata, Brady, 1884, Chall. Rep., p. 151, pl. IX, figs. 5, 6.

Frequent, most of the perfect specimens resembling Brady's fig. 6. The examples found in the 1893 gatherings are much worn and at times difficult to recognise.

(With one or two exceptions the specimens are calcite casts and specific determination can only be presumed. One good and distinctive specimen from Gathering 4.)

6. Spiroloculina impressa, Terquem.

Spiroloculina impressa, Terquem, 1878, Mem. Soc. Géol. France, (3), vol. 1, p. 53, pl. V, (X), fig. 8, a, b.
S. impressa, Brady, 1884, Chall. Rep., p. 151, pl. X, figs. 3, 4.

Well-preserved typical specimens were collected both in 1893 and 1897, and were not infrequent though seemingly confined to the pure marl beds forming the upper portion of the formation.

7. SPIROLOCULINA CANALICULATA, d'Orbigny.

Spiroloculina canaliculata, d'Orbigny, 1846, For. Foss. Vienne, p. 269, pl. XVI, figs. 10-12.

S. limbata, var., Brady, 1884, Chall. Rep., p. 150, pl. X, figs. 1, 2.

The species is rather rare in these marls and not typical, the chambers being few and broad and not so elongated as in the type, approaching more the form figured by Brady under the name "*S. limbata, var,*" though not so circular in contour. The oval extremity of the final chamber is slightly prolonged and connected with the periphery of the penultimate chamber by a web such as is seen in Brady's figures of *Spiroloculina acutimargo*.*

7A. [SPIROLOCULINA PLANULATA (Lamarck).]

[*Miliolites planulata*, Lamarck, 1804, AM. p. 352, No. 4, 1816, etc., Animaux sans vertèbres, Paris, 1822, vol. VII. p. 613, No. 4.

Spiroloculina planulata, Brady, 1884, FC. p. 148, pl. IX, fig. 11 *a, b*.]

8. SPIROLOCULINA ARENARIA, Brady.

Spiroloculina arenaria, Brady, 1884, Chall. Rep., p. 153, pl. VIII, fig. 12, a, b.

One specimen has been found which must be assigned to this species. Owing to the somewhat imperfect condition of the example, the produced shelly aperture as figured by Brady is wanting and on one side of the test the sutures of the chambers could not be made out. The other side and the contour of the transverse section as seen in a view taken from the oval end of the test agree well with Brady's drawings. After making drawings, which, however, do not appear in illustration of this paper, the specimen was broken up to obtain further evidence of identification, which corroborated the opinion formed upon the external features of the shell.

* 1884, Chall. Rep., pl. x. figs. 12-15.

9. Spiroloculina crenata, Karrer.

Spiroloculina crenata, Karrer, 1868, Sitz, k. Ak. Wiss. Wien., LVIII, Abth. 1, p. 135, pl. 1, fig. 9.
S. crenata, Brady, 1884, Chall. Rep. p. 156, pl. X, figs. 24-26.

Very rare, only one small specimen being found.

(The specimen is very small and not very typical. It shows a broad milioline aperture and is perhaps nearer to *Quinqueloculina plicatula*, Reuss, which Karrer referred to as being "very like" his species.)

10. [Spiroloculina dorsata, Reuss.]

[*Spiroloculina dorsata*, Reuss, 1870, Sitz. k. Ak. Wiss. Wien, vol. LXII, Abth. I, p. 97, pl. XXXVII, figs. 24-32.]

10a. Spiroloculina limbata, Bornemann.

Spiroloculina limbata, Bornemann, 1855, Zeitschr. deutsch. géol. Ges., vol. VII, p. 348, pl. XIX, fig. 1.
S. limbata, Reuss, 1863, Sitz. k. Ak. Wiss. Wien, vol. XLVIII Abth. I, p. 64, pl. VIII, figs. 89, a, c.

The specimens which I have thought necessary to assign to Bornemann's species are rare in my collections and closely resemble the figures given by Reuss; there are also some others (two or three) which are broader, and have not the same excessive sutural limbation, and conform more to the "*canaliculata*" type. These might be named *S. dorsata*, Reuss, but as the few specimens found are a good deal decomposed and worn it is not desirable to record that species definitely, though they very probably do belong to it. In making use of Bornemann's name as the authority for the specific appellation "*limbata*," I do not forget that d'Orbigny in 1826 made use of the same name, but it was not applied to the same form and is more applicable to the variety of *S. canaliculata* assigned by Reuss to *S. dorsata*, viz:—that with chambers having slightly limbate sutures or excavate lateral surfaces, and a square or very slightly rounded periphery. This mode of regarding these nearly allied forms will, I think, be found a convenient one, as the strongly limbate form above described may be regarded as an elongated *S. dorsata* which has put on an extra amount of sutural limbation, or as a *S. impressa* which has added a limbation to the already salient peripheral edges of its chambers. Moreover the reference of any specimens to the exact form figured by Reuss leaves no doubt as to the variety which is now recorded as occurring in the Biarritz marls.

(Halkyard apparently altered his opinion as regards the identification of these specimens, for the slide labelled *S. limbata* is empty and another, labelled "?*S. dorsata*, Reuss" appears in the collection, though not referred to in the MS. The few specimens on the slide are more or less fragmentary casts, but we have little hesitation in assigning them to *S. dorsata* The synonymies of the two forms have been referred to by us at some length in our Kerimba monograph. (H-A & E. 1914, etc., F.K.A. p. 554.))

GENUS MILIOLINA, Williamson.

11. MILIOLINA SEMINULUM (Linné.)

Serpula seminulum, Linné, 1767, ed. 12, p. 1264, No. 791.
Quinqueloculina triangularis, d'Orb., 1826, Ann. Sci. Nat., vol. VII, p. 302, No. 34.
Miliolina seminulum, Brady, 1884, Chall. Rep., p. 157, pl. V, figs. 6 a, b, c.

Not uncommon at Biarritz, the general type being short and broad. The most robust specimens viewed from the side have the contour of *M. auberiana*, d'Orb., but are less angular in transverse section than that species, which is intermediate between *M. seminulum* and *M. cuvieriana*, d'Orb. This broad form however is not constant, but in some instances becomes more like the type, viz.:—longer in proportion to the breadth; such specimens are usually small. In another direction it approaches *M. circularis*, Bornemann; and in yet another it merges almost imperceptibly into *M. venusta*, Karrer.

(There is considerable variety among the specimens assigned to *M. seminulum*, many of which are calcite casts difficult to identify with certainty, but the general type is of the variety *Quinqueloculina triangularis*, d'Orb. (d'O. 1846. F.F.V. p. 288 pl. XVIII, figs. 7-9.))

12. MILIOLINA CIRCULARIS (Bornemann).

Triloculina circularis, Bornemann, 1855, Zeitschr. deutsch. géol. Ges. vol. VII, p. 349, pl. XIX, fig. 4.
Miliolina circularis, Brady, 1884, Chall. Rep., p. 169, pl. IV, fig. 3 a, b, c, and pl. V. fig. 13, 14?

This species seems to replace *M. seminulum* in the lowest beds of the pure marl, at any rate it only appears in gatherings 7, 8, and 9 taken in 1893, whilst the above-mentioned form is at its highest development in Nos. 1, 2, and 3 Gatherings

and in those taken in April, 1897, which are also fairly high up in the series. It must not be understood from this that *M. seminulum* is absent from the lower beds, on the contrary it has even been found in the hardest and lowest beds of sandy and pure limestone.

(The majority of the specimens are casts, but are referable with tolerable certainty to *M. circularis*.)

13. Miliolina oblonga (Montagu).

Vermiculum oblongum, Montagu, 1803, Test. Brit., p. 522, pl. XIV, fig. 9.
Miliolina oblonga, Brady, 1884, Chall. Rep., p. 160, pl. V, fig. 4a, b.

This variety is rare at Biarritz and nearly all the specimens are small.

14. Miliolina trigonula (Lamarck).

Miliolites trigonula, Lamarck, 1804, Ann. Mus., V, 351, No. 3.
Miliolina trigonula, Brady, 1884, Chall. Rep., p. 164, pl. III, figs. 14-16.

Rare and small.

[There are a good many typical specimens of fair size on the type-slides.]

15. Miliolina tricarinata (d'Orbigny).

Triloculina tricarinata, d'Orbigny, 1826, Ann. Sci. Nat. VII, p. 299, No. 7.
Miliolina tricarinata, Brady, 1884, Chall. Rep., p. 165, pl. III, figs. 17a, b.

This form is rare and has only been found in the upper portions of the marl.

(The specimens are in good preservation and very large compared with those of *M. trigonula*. Both the long and short types are present.)

16. Miliolina venusta (Karrer).

Quinqueloculina venusta, Karrer, 1868, Sitz. k. Ak. Wiss. Wien., LVIII, Abth. 1, p. 147, pl. II, fig. 6.
Miliolina venusta, Brady, 1884, Chall. Rep., p. 162, pl. V, figs. 5 and 7.

Frequent through the whole series of gatherings but in the lower half of the beds is represented principally by calcite casts.

(Very fine and typical specimens from Gathering 3. Less marked and smaller from elsewhere. From several localities the specimens are represented only by casts and identification is often only a matter of opinion, as the casts might refer to any Miliolid of similar structure.)

17. MILIOLINA FERUSSACII (d'Orbigny).

Quinqueloculina ferussacii, d'Orbigny, 1826, Ann. Sci. Nat. VII, p. 301, No. 18.

Not rare and approaching *M. contorta* (d'Orb.) in form.

(Except from Gathering 1, the specimens are nearly all casts, and the specific features are therefore unidentifiable. From Gathering 1 the individuals are in our opinion nearer to *M. contorta* than *M. ferussacii*.)

18. MILIOLINA AGGLUTINANS (d'Orbigny).

Quinqueloculina agglutinans, d'Orbigny, 1839, De la Sagra, Hist. Phisiq. etc., Cuba, " Foraminifères," p. 195, pl. XII, figs. 11-13.

Miliolina agglutinans, Brady, 1884, Chall. Rep., p. 180, pl. VIII, figs. 6 and 7.

Rare and typical.

19. MILIOLINA BICORNIS (Walker & Jacob).

Serpula bicornis, Walker & Jacob, 1798, Adam's Essays Micr., p. 633, pl. XIV, fig. 2.

Miliolina bicornis, Brady, 1884, Chall. Rep., p. 171, pl. VI, figs. 9, 11, 12.

Very small and very rare.

(The few specimens from G. 3, represent several distinct types, the true *M. bicornis* being absent. They are very small and worn but so far as can be identified with certainty include *M. brongniartii* (d'Orb.), *M. boueana* (d'Orb.), and *M. striata* (d'Orb.).)

20. [Miliolina striata (d'Orbigny).]

20a. Miliolina poeyana (d'Orbigny).

Quinqueloculina poeyana, d'Orbigny, 1839, De la Sagra, Hist. Phisiq., etc., de Cuba. "Foraminifères," p. 191, pl. XI, figs. 25-27.

An elongated variety of *M. bicornis*, the chambers however being more circular in transverse section, and the costæ more strongly marked. Rare at Biarritz, only about half-a-dozen specimens being found in the 1897 Gatherings.

(The specimens are not referable to the Cuban species *M. poeyana*, but to the much more robust form *M. striata* (d'Orb.) with which we dealt at some length in our Kerimba Monograph (H-A & E. 1914, etc. F.K.A. p. 579, pl. XLIV, figs. 13-17.))

21. Miliolina parisiensis (d'Orbigny) var.

Quinqueloculina parisiensis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 301, No. 5.
Miliolina parisiensis, Millett, 1898, Journ. Roy. Micr. Soc., 1898, p. 504, pl. XII, fig. 1, a, b, c.

Only two specimens were found, one of which was so worn as to leave very little of the external characters visible. The other one on being placed in fluid displayed clearly the rectangular ornamentation shown in Millett's figure. My specimens are broader in proportion to length than those from the Malay Archipelago and also lack the produced ultimate chamber, but there is no doubt in my mind that they ought to be assigned to the above species.

(The specimens can only be regarded as unsatisfactory examples of an unsatisfactory species. One of the specimens is so worn as to be unidentifiable, except by its resemblance in contour with the other specimen which is covered with minute pits. No signs of striæ or costæ remain on the test, which in form is nearer *Quinqueloculina prisca*, Terquem than *parisiensis*. The specific name *M. parisiensis* has now become identified with Terquem's figure (T. 1882. F.E.P. p. 181, pl. XIX. (XXVII) fig. 21) of a common Paris Eocene fossil, which we identified and figured from similar material from Selsey Bill (H-A & E. 1908, etc., S.B., 1909, p. 315, pl. XV. figs. 3-5.) The Terquem form is covered with minute pits set in regular lines between the costæ; d'Orbigny's original name has only the descriptive definition added to it in the Prodrome (d'O. 1849 P.P. 1850. Vol. II. p. 409. No. 1364.)

"espèce renflée et striée" and his drawing from the Planche inédite as reproduced by Fornasini (F. 1905, S.O.M. p. 63. pl. II. fig. 9) shows no pitting, nor is any visible on d'Orbigny's type specimens which we have examined both in Paris and at La Rochelle. Terquem's figure has now become however so generally accepted for a determinate type that it seems impossible to depart from it. It must be borne in mind that he also had examined the d'Orbigny types and plates in Paris *

Yet another type with fairly distinctive features has been ascribed to this species by Millett (Millett, 1898, etc., F.M. 1898, p. 504, pl. XII. fig. 1 a, b, c). This represents a form with regular cross bars between longitudinal costæ, the depressions thus formed being apparently regarded as analagous to the pits in the Parisian Eocene type of Terquem.)

GENUS SIGMOILINA, Schlumberger.

22. SIGMOILINA TENUIS (Czjzek).

Quinqueloculina tenuis, Czjzek, 1848, Haidinger's Nat. Abh., vol. II, p. 149, pl. XIII, figs. 31-34.
Spiroloculina tenuis, Brady, 1884, Chall. Rep., p. 152, pl. X, figs. 7-11.

Found frequently and well-preserved through the whole thickness of the marl beds.

(The species is represented by an exceptionally fine series of specimens. The propriety of transferring the species from *Spiroloculina* to *Sigmoïlina* is we think open to question, especially when such a large and varying collection as the present one is considered. The *Sigmoïlina* curve is of the most rudimentary nature, although it is apparent in some of the many broken sections which have been mounted for the purpose of displaying it. In the majority of specimens especially in some Gatherings (notably G. 8) where the specimens are exceptionally large there is hardly the faintest deviation from a typical *spiroloculine* growth. It is very curious how this delicate little Miliolid has, generally speaking, escaped the erosion from which the other Biarritz Miliolids suffer. If Halkyard's theory of the disappearance of the Miliolid shell owing to a difference in its molecular composition, as compared with the shells of the perforate Foraminifera, is correct (see his Introduction) it points to a further difference in the constitution of the test of

* See O. Terquem, "Foraminifères de l'Eocene de Paris," Mem Soc. Geol. France, S.3, ii, Mem. 3 p.11 and E. Heron-Allen, "Alcide d'Orbigny," J. R. Mier. Soc. Presidential Address, 1917, p. 33.

S. tenuis as compared with other Miliolids. We have observed this in other fossil deposits, as in the Miocene clays of Malta in which *S. tenuis* is common and well preserved, while other Miliolids are represented by pyritic casts only.)

Genus Pentellina, Munier-Chalmas.

23. Pentellina lævis, sp. nov.

Pl. I, fig. 1.

Test elongated, five to seven chambers visible externally, periphery angular, the chambers being oval in transverse section and each having its own entire enclosing wall. Texture smooth and glistening, unornamented. Length, .75 to .95 mm. Breadth, .43 to .47 mm.

This rare form has been assigned on account of the arrangement of its segments to the genus *Pentellina* although it has the ordinary *Miliolina* aperture and does not exhibit the Trematophore which is characteristic of *P. saxorum* and *P. tournoueri*. There may be a question whether it is worth while making a special genus for those Miliolids which, though possessing the arrangement of chambers as provided for in the genus *Miliolina* possess a more complicated or more fully developed form of oral aperture.

24. [Miliolina angularis, Howchin.]

24a. Pentellina attenuata, sp. nov.

Pl. VIII, figs. 1 and 2.

Test very much elongated, five chambers visible externally, periphery angular, chambers flatter and longer in proportion to their width than in *P. lævis*. Texture smooth. Length, 1 to 1.25 mm. Breadth, .27 to .3 mm.

This species is rather more rare than *P. lævis*, and is easily distinguished from it by its much greater length and more slender proportions. The shell-wall is so fragile through decomposition that I have been unable to find a perfect specimen, and though the drawing here given is to a certain extent a restoration it may be taken as representing a typical specimen. The species has only been found in the beds of marl at the end of the sea-wall and is not plentiful there, only about a dozen specimens being found.

(Halkyard subsequently found many more specimens, most of which are perfect and are well represented by his figure.

These are on his type-slides. The Biarritz specimens are identical with *Miliolina angularis* Howchin (H. 1889 M.C.V. p. (reprint) 2, pl. I, figs. 1-3) from the Older Tertiary of Australia. The specific name *angularis* has been used by d'Orbigny for two Miliolids and Howchin's name is therefore somewhat unhappy. As, however, Triloc. angularis d'Orb = M. tricarinata and Q. angularis d'Orb. = M. contorta, and only one subsequent author, viz. Terquem, has employed either name, we think that Howchin's name might be allowed to stand.)

SUB-FAMILY HAUERININÆ.

Genus Articulina, d'Orbigny.

25. Articulina lævigata, Terquem.

Articulina lævigata, Terquem, 1882, Mém. Soc. Géol. France [3], vol. II, p. 151, pl. XV (XXIII), figs. 27-31.

Very rare, two imperfect specimens found in 1897 Gatherings.

(Terquem's species judging from his figures (*ut suprâ*) is unsatisfactory, there being no apparent connection between the figure showing a broken series of rectilinear chambers, and the series of abnormal miliolids which are associated with it in the plate. Halkyard's specimens are fragments, each consisting of parts of two chambers of the rectilinear series. In their smooth test they agree with Terquem's definition, but apart from this we should have been inclined to associate them with *A. conico-articulata* (Batsch.))

26. [Articulina sulcata, Reuss.]

[*Articulina sulcata*, Reuss, 1849-50, Foram. österr. Tertiarbeckens. Denkschr, k. Ak. Wiss, Wien, vol. i, (1850), p. 383, pl. IV, (XLIX) figs. 13-17.]

26a. Articulina conico-articulata (Batsch).

Nautilus (*Orthoceras*) *conico-articulatus*, Batsch, 1791, Conchyl. des Seesandes, p. 3, pl. III, fig. 11.
Articulina conico-articulata, Brady, 1884, Chall. Rep., p. 185, pl. XII, figs. 17, 18, and pl. XIII, figs. 1-2.

Rare, small, and only found in the immature stage without the linear series of chambers.

(The two small specimens on which the record rests should in our opinion to be referred to *A. sulcata*, Reuss.)

Genus Hauerina, d'Orbigny.

27. Hauerina fragilissima (Brady).

Pl. I, fig. 2.

Spiroloculina fragilissima, Brady, 1884, Chall. Rep., p. 149, pl. IX, figs. 12-14.
Hauerina fragilissima, Millett, 1898, Journ. Roy. Micro. Soc , p. 610, pl. XIII, fig. 8, also 9 and 10.

This species is not rare in my collections, though on account of its fragility it is rarely found perfect. Both the microspheric and the megalospheric forms are present. Of the former I show a transverse section. It will be seen that in the earlier portion of this form there is an apparent arrangement of the chambers in seven radial series before the shell takes on the spiroloculine manner of growth. If, however, the section is examined more closely it will be found that the chambers are really arranged in two involved opposed curves as in *Sigmoïlina* but in a more complicated manner as each series consists of about 2½ turns, after which it adopts the planospiral growth of *Spiroloculina*. The *Sigmoïlina* growth is much more easily seen in the megalospheric form, the chambers being fewer and larger. As for the *Hauerina* plan of growth it is at best only slightly indicated in my specimens, as in those figured by Millett and Brady, by a slight obliquity of the line of junction of the spiroloculine chambers to the longitudinal axis of the earlier thicker portion of the test. The imperfect state of the Biarritz specimens also does not permit of any definite verification of the form of the oral aperture.

This anomalous form may be perhaps with reason transferred to the genus *Sigmoïlina* but I am loth to recommend such a course at present, or until we have a fuller knowledge of the many variations of the milioline plan of growth, and besides, the earlier growth of a shell only shows us the line of departure from type, and the latter points towards the higher or lower type to which the particular form under observation is tending either progressively or retrogressively. In these circumstances I prefer to retain the generic name *Hauerina* for this species.

(The specimens are small and poorly developed but appear to be referable to *Spiroloculina tateana*, Howchin, from the Tertiary of Muddy Creek, Victoria.* Howchin's species is clearly referable to the sub-genus Massilina owing to the pronounced milioline arrangement of the early chambers before

* Trans. R. Soc. S. Austr. vol. xii. 1889, p. 3, pl. I., figs. 4, 5.

they take on the angular spiroloculine plan of growth. On the other hand Halkyard's suggestion that *Hauerina fragilissima* would be better transferred to *Sigmoïlina* does not commend itself to us, as a slight sigmoïline arrangement of the earliest chambers is of more or less frequent occurrence in many Miliolids, and should not in our opinion be regarded as of final importance in the determination of the genus.)

SUB-FAMILY PENEROPLIDINÆ.

Genus Cornuspira, Schultze.

28. Cornuspira involvens, Reuss.

Cornuspira involvens, Reuss, 1863 (1864), Sitz. k. Ak. Wiss. Wien, vol. XLVII (1), p. 39, pl. 1, fig. 2.
C. involvens, Brady, 1884, Chall. Rep., p. 200, pl. XI, figs. 1-3.

Specimens very small and rare.

(As all the specimens are represented by casts, specific identification appears to be a matter of opinion. The casts represent at least two different forms.)

29. Cornuspira foliacea (Philippi).

Orbis foliaceus, Philippi, 1844, Enum. Mollusc. Siciliæ, vol. II, p. 147, pl. XXIV, fig. 26.
Cornuspira foliacea, Brady, 1884, Chall. Rep., p. 199, pl. XI, figs. 5-9.

Specimens are small and rare, and do not show the rapidly widening whorls which are characteristic of the species, being of the form represented by Brady's figure 6 (*ut suprâ*). One at least of the examples might possibly be referred to Bornemann's *C. reussi*.

(The specimens are of the original Philippi type, not of the rapidly expanding type subsequently figured by Williamson. Some of the specimens are near *C. carinata* (Costa).)

30. Cornuspira crassisepta, Brady.

Cornuspira crassisepta, Brady, 1882, Proc. Roy. Soc. Edinburgh, vol. XI, p. 714.
C. crassisepta, Brady, 1884, Chall. Rep., p. 202, pl. CXIII, fig. 20.

Very rare, one specimen only found in Gathering No. 1, 1893. This single example corresponds closely with Brady's description and figure.

(The specimen agrees very closely with the original description of the species. Brady's subsequent figure is not altogether satisfactory, the limbation being somewhat irregularly shown.)

SUB-FAMILY ALVEOLININÆ.

Genus Alveolina, d'Orbigny.

31. Alveolina boscii (Defrance).

Oryzaria boscii, Defrance, 1820, Dict. Sci. Nat., vol. XVI. p. 104 sub *Fabularia*; Atlas Zooph., pl. XLVIII, fig. 4.
Alveolina boscii, (d' Orbigny), 1826, Ann. Sci. Nat. vol. VII, p. 306, No. 5.
A. boscii, Brady, 1884, Chall. Rep., p. 222, pl. XVII, figs. 7-12.

Very rare. In the uppermost gathering taken behind and above the Bathing Establishment was found one small broken cast in pyrites which bore some traces of the porcellanous shell wall.

(This cast seems to us probably to be a derived fossil. If *Alveolina* were present at all in a gathering it would almost certainly be of frequent occurrence.)

FAMILY ASTRORHIZIDÆ.

SUB-FAMILY ASTRORHIZINÆ.

Genus Astrorhiza, Sandahl.

32. Astrorhiza granulosa, Brady.

Astrorhiza granulosa, Brady, 1881, Quar. Journ. Micr. Soc., vol. XXI, p. 48.
A. granulosa, Brady, 1884, Chall. Rep., p. 234, pl. 20, figs. 14-23.

I have assigned to this species a single example found in 1893. On comparing this specimen with Brady's figures I find that it is broader in proportion to the length and does not possess the same produced orifices, being in form almost similar to *Technitella melo*, Norman, though having an aperture at each end of the test. My specimen is also much smaller than those described by Brady, the length of which is noted as at least $\frac{1}{4}$ in., whilst mine is but 7/100ths of an inch long. The test of the Biarritz example is more consolidated than that of recent specimens, but that is easily accounted for by the supposition that lime chemically concreted from the enclosing marl has supplemented the ordinarily-deficient cement of the test in this species and so tended to make the shell-wall more

solid. This view is supported by the fact that my single specimen is greyish white in colour and certainly shows a larger proportion of cement to sand than is usual.

(The specimen is most unconvincing. We are not even satisfied that it is a Rhizopod. The specimen differs in everything—shape—texture—aperture—from the type, which would be very unlikely to survive fossilization owing to its construction.)

GENUS PSAMMOSPHAERA, Schulze.

32A. [PSAMMOSPHAERA FUSCA, Schulze.]

[*Psammosphæra fusca*, Schulze, 1874, R. p. 113, pl. II, fig. 8.
Psammosphæra fusca, Brady, 1884, FC. p. 249, pl. XVIII, figs. 1-8.]

SUB-FAMILY RHABDAMMININÆ.

GENUS ASCHEMONELLA, Brady.

33. ASCHEMONELLA CATENATA (Norman).

Pl. I, fig. 3.

Astrorhiza catenata, Norman, 1876, Proc. Roy. Soc., vol. XXV, p. 213.
Aschemonella catenata, Brady, 1884, Chall. Rep., p. 271, pl. XXVII, figs. 1-11; and pl. XXVII A, figs. 1-3.

Two fragments consisting of three chambers were found in 1893. As will be seen from the drawing here given this closely resembles in the form of the chambers one of the figures given by Brady (fig. 4, pl. XXVII). My specimens have perhaps a slightly rougher test and have the chamber cavities filled with calcite.

FAMILY LITUOLIDÆ.

SUB-FAMILY LITUOLINÆ.

GENUS REOPHAX, Montfort.

34. REOPHAX FUSIFORMIS (Williamson),

Proteonina fusiformis, Williamson, 1858, Recent British Foram. p. 1, pl. I, fig. 1.
Reophax fusiformis, Brady, 1884, Chall. Rep., p. 290, pl. XXX, figs. 7-11.

Very rare, one specimen only found.

(This specimen is not in our opinion identifiable with certainty.)

35. Reophax scorpiurus, Montfort.

Reophax scorpiurus, Montfort, 1808, Conch. Syst. 1, p. 331, 83rd genre.

R. scorpiurus, Brady, 1884, Chall. Rep., p. 291, pl. XXX, figs. 12-17.

Rare and small, the specimens being sometimes compressed and not circular in transverse section. May be *R. arctica*, Brady.

(Certainly not *R. arctica*, as suggested by Halkyard, which is a delicate thin-walled linguline form, whereas these are built up of coarse sand grains. Their compressed form is due to their fossil condition.)

36. Reophax plana, sp. nov.

Pl. I, figs. 4, 5.

Test compressed, consisting of two or three sub-discoidal chambers arranged in a linear series, each chamber being larger than the preceding one. Texture coarsely arenaceous. Length, 1.15 to 1.55 mm. Breadth, .85 to 1.5 mm.

Out of the four specimens found only one has three chambers and, as will be seen from my drawing is smaller and not so robust as the other three specimens, which had only two chambers each.

The nearest ally of this new species is Brady's *Reophax arctica** which is formed of about eight chambers forming a gradually-tapering test rather pointed at the aboral extremity, and compressed so that the width at any one point is about double the thickness at the same point.

Goës also figures † a compressed *Reophax* under the name of *R. compressus*, which he remarks is nearly related to *Haplophragmium tenuimargo*, Brady. His examples have five or six chambers and an approximately parallel contour.

(The type specimens have not been found, but the description suggests *Haplophragmium calcareum* Brady or *H. pseudospirale* (Will), certainly not *Reophax arctica*.)

* Denkschr. k. Ak. Wiss. Wien, vol. XLIII, 1881, p. 99, pl. 2, fig. 2 and Ann. Mag. Nat. Hist. Ser. V. vol. VIII, 1881, p. 405, pl. XXI, fig. 2.

† A Synopsis of the Arctic and Scandinavian Recent Marine Foraminifera, 1894, Stockholm, p. 27, pl. VI, figs. 203-210.

37. [NOURIA POLYMORPHINOIDES, Heron-Allen & Earland.]

[*Nouria polymorphinoides*, Heron-Allen & Earland, 1914, etc., F.K.A., p. 376, pl. XXXVII, figs. 1-15.]

37A. REOPHAX POLYMORPHINOIDES, sp. nov.

Pl. I, figs. 6, 7.

Test elongate, compressed, consisting of an aggregation of compressed sub-discoidal chambers arranged in such a manner as to bear a strong external resemblance to *Polymorphina*. Texture roughly arenaceous. Length, 1.4 to 2.7 mm. Breadth, .82 to 1.15 mm.

This species is not very rare in the Blue Marl. Its form is rather variable, sometimes it occurs with characteristics as well marked as those here figured but quite as many examples are found which are by no means easy to identify, as they appear externally to be only fortuitous agglomerations of particles of quartz, and can only be recognised by the company in which they are found. It will be seen from fig. 7 that in the immature stage the test is an arenaceous isomorph of *Polymorphina problema*, d'Orb., whilst later it assumes more of the character of *P. compressa* d'Orb. Unfortunately, I have not been able to make out the position and form of the oral aperture.

(Halkyard's specimens are clearly referable to our genus Nouria (*ut suprâ*), and probably to our species *N. polymorphinoides* of the large type found at Kerimba. They differ in their rougher and less finished construction and in the greater compression of the test, but this compression is variable in the Biarritz specimens and is probably due to pressure in the fossilization. For taxonomic purposes it may perhaps be advisable to separate the Biarritz specimens as a variety *N. polymorphinoides* var *halkyardi*.)

GENUS HAPLOPHRAGMIUM, Reuss.

38. HAPLOPHRAGMIUM AGGLUTINANS (d'Orbigny.)

Spirolina agglutinans, d'Orbigny, 1846, Foram. Fossiles Vienne, p. 137, pl. VII, figs. 10-12.
Haplophragmium agglutinans, Brady, 1884, Chall. Rep., p. 301, pl. XXXII, figs. 19-26.

Rather rare, stout in form and coarsely arenaceous in texture.

(The specimens are all of a large and roughly agglutinate

type, built up of angular sand grains and particles of calcareous matter. There is no selective tendency as recorded by us from several widely separated gatherings.)

39. Haplophragmium pseudospirale (Williamson.)

Proteonina pseudospiralis, Williamson, 1858, Recent British Foram., p. 2, pl. I, figs. 2-3.
Haplophragmium pseudospirale, Brady, Chall. Rep., p. 302, pl. XXXIII, figs. 1-4.

Not rare, distributed through the whole thickness of the marl. The majority of the specimens however were found in Gathering No. 5, 1893.)

(Some of the specimens can only be accepted with reservation owing to their condition, but large and typical examples are represented from Gathering 5.)

39a. [Haplophragmium tenuimargo, Brady.]

[*Haplophragmium tenuimargo,* Brady 1882, KE. p. 715.
H. tenuimargo, Brady, 1884, FC. p. 303, pl. XXXIII, figs. 13-16.]

40. Haplophragmium æquale, (Roemer).

Spirolina æqualis, Roemer, 1840-1, Verst. norddeutsch Kreide, p. 98, pl. XV, fig. 27.
Haplophragmium æquale, Reuss, 1860, Sitz. k. Ak. Wiss. Wien, vol. XL, p. 218, pl. XI, figs. 2 a, b, and 3 a, b.

Frequent, but sometimes difficult to distinguish from *Clavulina cylindrica,* Hantken, on account of the material of which the test is composed being the same in both species as found at Biarritz, and also by the regularity of growth and closely-fitting chambers of the species now under consideration, which, in some cases, can only be recognised by a slight obliquity of the aboral portion of the test. Longitudinal sections, however, show the true nature of the organism. Other specimens approach more closely to those figured by Reuss and those found in the Gault of Folkestone by Chapman.

(Halkyard's sections leave no doubt as to the correctness of his generic determination, but the specimens are very variable and are more smoothly constructed than is usual in this species. The records appear to be exclusively confined to the Cretaceous series, and its extension into the Eocene at Biarritz is noteworthy.)

41. HAPLOPHRAGMIUM CONCAVUM, Bagg.

Haplophragmium concavum, Bagg., 1898, Cretaceous Foram. of New Jersey, p. 27, pl. II, figs. 1a, 1b, U.S., Geol. Survey, Bulletin, No. 88.

This species is rare in the Biarritz Marl. It seems, by its form, to grow lightly attached to some foreign body, though I must say that I have not found it so growing, possibly its only attachment is by the living sarcode. It is an isomorph of *Placopsilina cenomana*, d'Orb., from which it is chiefly distinguished by its more robust character, and more close-cemented shell-wall. It has also a proper shell wall on the inferior or attached surface, which is generally slightly concave.

My specimens have more chambers and are more irregular in growth than that figured by Bagg, and are also rougher in texture judging from his drawings.

(Halkyard's specimens are rather striking, but the texture of the shell appears to us to be much too rough to identify them with Bagg's species, as shown in his figure. The possibility that both Halkyard's and Bagg's specimens may be merely detached and abnormal *Placopsilinæ* requires to be considered in connection with a larger series of specimens than is available.)

42. HAPLOPHRAGMIUM RUGOSUM, (d'Orbigny).

Robulina rugosa, d'Orbigny, 1826, Ann. Sci. Nat., VII, p. 290, No. 21.

Haplophragmium rugosum, Brady, 1888, Quart. Journ. Geol. Soc., vol. XLIV, p. 4, pl. I, fig. 2.

A few examples of this form, with coarse arenaceous walls, and chambers hardly discernible on the exterior, were found in the miscellaneous Gatherings of 1893 and 1897.

(The Biarritz specimens are all very coarsely agglutinate as compared with either Soldani's or Brady's figures, but the identification is, we think, admissible.)

43. HAPLOPHRAGMIUM TUMIDUM, sp. nov.

Pl. 1, fig. 9.

Test spiral, nautiloid, thick in the centre, thinning rapidly towards periphery which is obtusely rounded. Segments few, of which the last convolution completely encloses the preced-

ing ones, divisions between the chambers not visible externally. Texture, coarsely arenaceous. Diam. .65 to 1 mm.

Beyond describing this species as resembling a much thickened variety of Hantken's *H. acutidorsatum* there is very little to be said about it. It is rather rare, occurring chiefly in the beds exposed at low water at the end of the sea-wall.

(We must confess that we can make very little of Halkyard's specimens, and the species must be accepted on the evidence of his description and the figures on the plate. The septation is very obscure and the fractured sections render any definite identification of a spiral arrangement of the chambers almost impossible. We should have inclined almost to the opinion that the chambers were arranged in a linear series, thus making it an isomorph of *Lingulina carinata* d'Orb., but Halkyard probably worked out his diagnosis by means of destruction of other specimens not now available for examination.)

44. Haplophragmium calcareum, Brady.

Haplophragmium calcareum, Brady, 1884, Chall. Rep., vol. IX, p. 302, pl. XXXIII, figs. 5-12.

Rare and found only in one gathering, viz., in sandy light-coloured marl from the top of the Cliff at a spot about 200 yds. south of the villa l'Ermitage. Brady notes this species from six of the "Challenger" stations, five of which are in tropical seas. I ought to remark that my specimens are more arenaceous in texture than Brady's, and the recent specimens in my own collection, but this variation in texture may arise from decomposition of the calcareous cementing substance.

(The specimens appear to us to be quite characteristic and there is no doubt as to Halkyard's identification.)

Genus Haplostiche, Reuss.

45. Haplostiche soldanii, (Jones & Parker).

Lituola soldanii, Jones & Parker, 1860, Quart. Journ. Geol. Soc., vol. XVI, p. 307, No. 184.

Haplostiche soldanii, Brady, 1884, Chall. Rep., p. 318, pl. XXXII, figs. 12-18.

This form does not occur frequently in the Marl and is rather small and slender in form. It was only by making

sections and breaking up several specimens that their true nature could be recognized. Owing to the infiltration by calcite of the specimens it has not been possible to make a section from which a satisfactory drawing could be made, and this infiltration has also obscured the terminal orifices.

Found in Gatherings 5, 7, 9. Also top of Cliff 200 yds. S. of l'Ermitage, Ap., 1902.

(The species is mainly represented by fragments, but there are three more or less perfect specimens from Gathering 5 which confirm the identification).

GENUS PLACOPSILINA, d'Orbigny.

46. [IRIDIA DIAPHANA, Heron-Allen & Earland,]

[*Iridia diaphana*, Heron-Allen & Earland, 1914, etc., F.K.A., p. 371, pl. XXXVI, and 1915, p. 607.]

[*Iridia diaphana*, Heron-Allen & Earland, 1916, F.S.C., p. 37.]

46A. PLACOPSILINA INTERMEDIA, sp. nov.

Pl. I, fig. 8.

Test adherent, roughly arenaceous, consisting of three or four chambers, arranged in a single curved series, each chamber being larger than its predecessor, divisions between the chambers not distinctly visible on the exterior except that separating the last from the penultimate one. Orifice small, situated on the longitudinal axis of the test close to the line of attachment to the foreign body. Length, 1.35 mm.

Only one specimen of this form has been met with, consequently I am somewhat diffident in creating a new species for it. At the same time the example has characteristics which seem to call for a distinctive name. Its nearest ally is *P. cenomana*, d'Orb. from which it can readily be distinguished by its tapering outline, and want of the spiral commencement which is so clearly marked in d'Orbigny's species.

(We have examined Halkyard's single specimen very carefully. It has grown attached to a very thin fragment of a molluscan shell and when examined on the underside shows at one corner where the shell is broken away, a thin membraneous lining free from arenaceous particles, which originally formed the floor of the test. It would therefore appear to come under the diagnosis of *Iridia diaphana* H-A. & E., assuming that this basal wall was originally chitinous, which cannot of course be proved in its fossil condition.)

47. Placopsilina aggregata, sp. nov.

Pl. VIII, figs. 3, 4.

Test adherent, sub-conical in form, arenaceous, rough and thick; consisting of about five chambers, which are variable in form, and have no floor on the attached surface. Aperture, a simple arched opening in the wall of chamber where applied to the object to which the test is affixed. Greatest diam. 1.02 mm.

Two specimens (one of which is broken) have been found. They are both attached to worn fragments of *Operculina complanata* and, as both are figured here, little remains to be said about them. It may, however, be remarked that though the arrangement of the chambers in the two specimens seems to be similar, it is difficult to make out what that arrangement is, and especially what place in the series the apical chamber actually occupies. The specimens cannot be assigned to any other arenaceous species found in these gatherings, or considered as immature forms of such species, so I am driven to create a new species for them much as I dislike to multiply the already overburdened nomenclature of the Foraminifera.

(The absence of any definite floor, beyond a thin film on the surface of the *Operculina* to which the specimens are attached, which was originally probably chitinous, leaves little doubt in our mind, when taken in connection with the rough texture of the wall, that these specimens should be referred to our species *Iridia diaphana*. (See our note to No. 46.)

47a. [Placopsilina cenomana, d'Orbigny.]

[*Placopsilina cenomana*, d'Orbigny, 1850, etc., PP. vol. ii, 1850, p. 185, No. 758.
P. cenomana, Brady, 1884, FC. p. 315, pl. XXXVI, figs. 1-3.]

Genus Bdelloidina, Carter.

48. Bdelloidina aggregata, Carter.

Bdelloidina aggregata, Carter, 1877, Ann. Mag. Nat. Hist., (4), vol. XIX, p. 201, pl. XXII, figs. 1-8.
B. aggregata, Brady, 1884, Chall. Rep., p. 319, pl. XXXVI, figs. 4-6.

Rare, and variable in the proportions of the chambers.

(The previous fossil records appear to rest on Brady's mention that Prof. Rupert Jones possessed a drawing of a specimen adhering to a cretaceous Annelid. Chall. Rep. *ut supra*, p. 320.))

GENUS AMMODISCUS, Reuss.

49. AMMODISCUS MILIOLOIDES, (Jones, Parker & Kirkby).

Pl. I, fig. 10.

Trochammina milioloides, Jones, Parker & Kirby, 1869, Ann. Mag. Nat. Hist., ser. 4, vol. IV, p. 390, pl. XIII, figs. 9-14.

T. milioloides, Brady, 1876, Carboniferous and Permian Foraminifera, Palæontograph. Soc., vol. XXX, p. 79, pl. III, figs. 11-15.

The specimens figured by Brady in the work above noted are not so much compressed as those found in the Blue Marl. In other respects the examples from both localities agree fairly well. The test is formed of fine material and is of dull whitish colour. Only three specimens, one imperfect, have been found at Biarritz, and a drawing is here given of the most typical one.

(The specimens have much more numerous and narrower chambers than in the typical *Trochammina milioloides* as figured in the references given by Halkyard, and in our opinion would be more properly referred to *Ammodiscus pusillus* (Geinitz), but the line of demarcation between these two forms is so slight that we think the later name *milioloides* is entirely superfluous. Geinitz's species should include all the allied forms.)

COLUMELLA, gen. nov.

50. [CARPENTERIA PROTEIFORMIS, Goës.]

Carpenteria balaniformis, var. *proteiformis*, Goës, 1882, Retic. Rhizop. Caribb. Sea, p. 94, pl. VI. figs. 208-214, pl. VII, figs. 215-219.

Carpenteria proteiformis, Brady, 1884, Chall. Rep., p. 679, pl. XCVII, figs. 8-14.]

50A. COLUMELLA CARPENTERIÆFORMIS, sp. nov.

Pl. II, figs. 1-5.

Test adherent by a spreading base, columnar, irregularly spiral and conical, in the young adherent portion, as successive chambers are added on the mode of growth gradually changing from a spiral to an approximately linear and erect series. Shell-wall thin and finely-arenaceous. Aperture, terminal, in a short mammiliform process, set excentrically with regard to the longitudinal axis of the last chamber. Height of erect specimens, .95 to 1.45 mm.

The only species which has been found and which is here described, is an isomorph of *Carpenteria proteiformis* Goës. In fact on a cursory examination my examples were thought to belong to that species but a second glance showed that a very different form had been discovered, and one that merited the formation of a new genus to receive it.

The tests are not all formed on the exact model described above, which is only of general application, but they follow various modifications of it. It has therefore been deemed necessary to give a series of drawings illustrating the different forms observed.

The more regularly formed tests commence by a spiral series of three or four chambers somewhat resembling *Truncatulina lobatula* (W. & J.). The last chamber of this series is narrower and about double the height of its predecessor. Its oval aperture is situated at its highest point. It is on the summit of this higher and narrow chamber that the next one is added so that the test now assumes a tower-shaped or columnar form.

The shell-wall is finely arenaceous, compact, smooth internally and white in colour.

This new genus is nearly related to *Trochammina* by its preliminary spiral growth, and to *Hormosina* by the form of its latter segments, the composition of its shell-wall and the character of its oral apertures.

In the only gathering (No. 5) where this form was found it was frequent and the specimens were sometimes filled with calcite and sometimes with pyrites.

(Halkyard's diagnosis of his specimens appears to have been somewhat perfunctory. A closer examination of the material and especially of the broken and ground down (opaque) sections which he had prepared would have disclosed the fact that the wall of the test was not truly arenaceous, but consisted of an inner calcareous and finely perforated shell incrusted with a thinner layer of very minute mud particles.

The existence of a similar double wall has been long known to exist in many *Textulariæ* and is not considered of even subgeneric importance.

Except in respect of this outer investing coat and the fineness of the perforations of the inner wall the specimens do not differ appreciably from *Carpenteria proteiformis*, Goës, and the presence of typical coarsely perforate fragments of this species in the Biarritz strata need not in our opinion prevent the sub-arenaceous specimens, assigned by Halkyard to a new genus, from being regarded as mere variations of Goës' protean type.

This opinion is strengthened by the evidence afforded by a thin transparent section which we have prepared from one of Halkyard's specimens, which in addition to the double shell wall reveals the fact that the walls of successive chambers are distinct, and sometimes separated by a distinct canal structure as in *Carpenteria*. The paucity of material has prevented us from confirming our observations by means of further sections.

The question whether Halkyard's specimens are identical with the curious form described by Liebus from Biarritz under the name *Karreria lithothamnica* (Uhlig) and similar forms described by Uhlig, Rzehak and Hantken from Central European Tertiary deposits under various names, *Karreria* (*Carpenteria*) *lithothamnica*, *Rupertia stabilis*, *Rupertia incrassata*, *Nubecularia elongata* (= *budensis*) must remain open, pending a comparison of the specimens with the types of those authors. Both descriptions and figures suggest that they are all mere variations of Goës' type *Carpenteria proteiformis*.

For the literature of these somewhat complicated questions of diagnosis see (i) V. Uhlig. Ueber eine Mikrofauna aus dem Alttertiär der westgalizischen Karpathen. Jahrb. der k.k. geol. Reichsanst, 1886, Vol. I. pt. 1, pp. 184-189. (ii.) A. Rzehak. Die Foraminiferenfauna der alttertiären Ablagerungen von Brudendorf in Niederoesterreich. Ann. des k.k. nat. Hofmuseums, 1891, Vol. VI. pt. 1, p. 6. (iii.) A. Rzehak. Ueber einige merkwurdige Foraminiferen aus dem œsterreichischen Tertiär. Ibid. 1895, Vol. X. pt. 2, p. 226. (iv) A. Liebus. Ueber die Foraminiferenfauna der Tertiärschichten von Biarritz. Jahrb. der k.k. geol. Reichsanst, 1906. Vol. II, pt. 2, p. 361.)

FAMILY TEXTULARIDÆ.

SUB-FAMILY TEXTULARINÆ.

GENUS TEXTULARIA, Defrance.

51. TEXTULARIA TROCHUS, d'Orbigny.

Textularia trochus, d'Orbigny, 1840, Mém. Soc. Géol., France, (1), p. 45, pl. IV, figs. 25, 26.
T. trochus, Brady, 1884, Chall. Rep., p. 366, pl. XLIII, figs. 15-19 and pl. XLIV, figs. 1-3.

Typical, and common, particularly in the upper half of the beds examined. In some broken specimens which have been found the porous nature of the test is most clearly shown owing to its being infiltrated by pyrites which contrasts strongly with the grey colour of the sandy test.

51a. [Textularia conica, d'Orbigny.]

[*Textularia conica*, d'Orbigny, 1839, F.I.C. p. 143, pl. I. figs. 19, 20.

Textularia conica, Brady, 1884, F.C. p. 365, pl. XLIII, figs. 13, 14, pl. CXIII, fig. 1.]

52. Textularia agglutinans, d'Orbigny.

Textularia agglutinans, d'Orbigny, 1839. In De la Sagra's Hist. Physique de Cuba, "Foraminifères," p. 144, pl. I, figs. 17, 18, and 32-34.

T. agglutinans, Brady, 1884, Chall. Rep., p. 363, pl. XLIII, figs. 1-3.

This form is small but not rare, and varies considerably in its contour and the form of the chambers.

53. Textularia agglutinans, var. porrecta, Brady.

Textularia agglutinans, var. *porrecta*, Brady, 1884, Chall. Rep., p. 364, pl. XLIII, fig. 4.

This elongated variety is frequent in the marl and is much larger than its type species, which is small in these gatherings. My specimens differ from Brady's by being more pointed and tapering at the aboral end of the test. This taper soon gives place to a parallel-sided contour and in some cases the shell diminishes in diameter again in the last one or two pairs of chambers. The test has sometimes as many as twenty-four chambers and attains a length of 1/16 inch.

54. Textularia gramen, d'Orbigny.

Textularia gramen, d'Orbigny, 1846, Foram. Fossiles Vienne, p. 248, pl. XV, figs. 4-6.

T. gramen, Brady, 1884, Chall. Rep., p. 365, pl. XLIII, figs. 9, 10.

Rare and small.

55. Textularia abbreviata, d'Orbigny.

Textularia abbreviata, d'Orbigny, 1846, Foram. Fossiles Vienne, p. 249, pl. XV, figs. 7-12.

T. abbreviata, Brady, Parker & Jones, 1888, Trans. Zool. Soc., vol. XII, pt. 7, p. 219, pl. XLII, figs. 4, 5.

Very rare. A solitary specimen being found about the middle of the Beds. This example differs somewhat from d'Orbigny's figures inasmuch as the chambers have not the same degree of backward curvature but are more horizontal, however there is no doubt of its belonging to the species to which I have assigned it.

(The single specimen is somewhat more angular than in d'Orbigny's figure and represents a passage form into *T. gramen*.)

56. TEXTULARIA CONCAVA (Karrer).

Flecanium concavum, Karrer, 1868, Sitz. k. Ak. Wiss. Wien, vol. LVIII, Abth. 1, p. 129, pl. I, fig. 3.
Textularia concava, Brady, 1884, Chall. Rep., p. 360, pl. XLII, figs. 13, 14; and pl. XLIII, fig. 11.

Not rare, but almost absent from the upper beds of the Marl, becoming more frequent in Gatherings 7, 8, and 9. The specimens resemble Karrer's figures rather than those given by Brady, being considerably depressed along the median line and having the sutures and margins of the chambers limbate.

57. TEXTULARIA GLOBULOSA, Ehrenberg.

Textularia globulosa, Ehrenberg, 1838, Abhandl k. Ak. Wiss. Berlin, p. 135, pl. IV, fig. B frequens.

Frequent and generally distributed.

58. TEXTULARIA FOLIUM, Parker & Jones.

Textularia folium, Parker & Jones, 1865, Phil. Trans., p. 370, pl. XVIII, fig. 19.
T. folium, Brady, 1884, Chall. Rep., p. 357, pl. XLII, figs. 1-5.

Rare, occurring only in Gatherings 8 and 9. The specimens are small, and the species is evidently not in a habitat favourable to its growth.

(The main specimens though probably referable to *T. folium* can hardly be described as satisfactory, but a typical example occurs on one of the type slides. This appears to be the first fossil record of the species, but we have met with it (very rarely) in the Eocene of Spring Creek, Moorabool River, Victoria, where the specimens are curiously similar to those from Biarritz. The difference between these fossil specimens, and the recent type is more prob-

ably due to development than to a starved habitat of the fossil specimens, which in our opinion are normally developed.)

59. Textularia sagittula, Defrance.

Textularia sagittula, Defrance, 1824, Dict. Sci. Nat. vol. XXXII, p. 177; vol. LIII, p. 344; Atlas Conch., pl. XIII, fig. 5.

T. sagittula, Brady, 1884, Chall. Rep., p. 361, pl. XLII, figs. 17, 18.

Specimens are not rare, and as they differ a good deal from the type they merit a detailed description. In the first place they are broad in proportion to their length, in this respect approaching to Hantken's *Textularia subflabelliformis*, they also resemble that variety in having the transverse sutures sloping backwards from the median line instead of being horizontal as in the type. There is again another difference in that the chambers are much more numerous amounting sometimes to as many as thirty (Hantken's species has only about twelve). For the rest, the Biarritz specimens are generally sharp pointed at the aboral extremity and increase rapidly in width, but rarely become parallel-sided. The periphery is sharp but not carinate. In the great majority of the specimens the commencement of the test is seen to be spiral, the spire consists of a globular primordial cell partially surrounded by four crescentiform chambers; the next one added is placed so as to form with the fifth the first pair of the alternating series which is typical of the genus. A very few of the specimens collected are of the typical biserial form from the commencement. These two forms are not always easy to differentiate from an external examination, but with care the true plan may generally be seen without making a section of the test.

Similar pairs to the foregoing have been noticed by Chapman in other Textularian species found in the Gault of Folkestone, viz.:—*T. complanata*, Reuss, *T. prælonga*, Reuss, *T. anceps*, Reuss. Chapman remarks "possibly the two genera of *Textularia* and *Spiroplecta* are in some way connected with the obscure problem of dimorphism." Now this seems to me extremely likely, and I should not be surprised to find that in a short time we had to discontinue the use of the generic term *Spiroplecta*, the species assigned to which will be all referred to their Textularian type.

(Our views upon this question, which coincide with those of Halkyard, are set out at length in our Clare Island Monograph. (H-A. & E. 1913. C.I. p. 57.))

60. TEXTULARIA BIARRITZENSIS, sp. nov.

Pl. II, fig. 6.

Test free, elongate, rectangular with rounded corners in transverse section, laterally compressed in the opposite direction to that usual with *Textularia*. Aboral extremity obtusely pointed. Sutures very slightly excavated, Chambers margined with a clear shell deposit. Texture smooth. Length, .45 mm.

This small form is very rare, only one specimen being found at Biarritz. The colour of this single specimen is yellowish brown, being to all appearance stained with iron oxide. The degree of depression is such as to make the side of the test on which both series of chambers can be seen only one half the width of that side showing the orifice and one series of chambers only. The aboral portion of the shell is faintly striate, and the sutures are occasionally faintly pitted.

In 1895, A. Rzehak figured a somewhat similar variety under the name of *Pseudotextularia varians**. My shell differs from the above-named chiefly in being more square in transverse section, more obtuse at the aboral end, and less tapering in outline as viewed from the biserial side. It will be seen from the figure here given that, as regards the last characteristic mentioned, my specimen tapers towards both ends of the test.

(The colour and general appearance of the specimen suggests a derived fossil of cretaceous origin, and this also appears to have been Halkyard's view, as a note among his MSS. states that "it may possibly be a derived fossil from the underlying cretaceous beds, as its colour, rather iron stained and general state of preservation is somewhat different from the other Foraminifera found in the Biarritz Marl." Rzehak's figure referred to by Halkyard has only a limited resemblance to the specimen. Halkyard's specimen appears to have more points of identity with d'Orbigny's little known genus *Cuneolina* with whch we have dealt elsewhere, and which was of cretaceous derivation. (Heron-Allen, J. R. Micr. Soc. 1917, p. 77.) The curious variety of *Textularia trochus* figured by Goës (G. 1882, R.R.C.S. p. 80, pl. V, figs. 167-170) is also very nearly allied to Halkyard's type.)

GENUS BIGENERINA, d'Orbigny.

61. BIGENERINA PENNATULA (Batsch).

Nautilus (*Orthoceras*) *pennatula*, Batsch, 1791, Conch. Seesandes, pl. IV, figs. 13a-13c.

* Ann. K. K. Naturhist. Hofmus. Wien, 1895, Band X. (2) p. 217, pl. VII, figs. 1-3.

Bigenerina pennatula, Brady, 1884, Chall. Rep., p. 373, pl. XLV, figs. 5-8.

Rather rare. Out of sixteen specimens collected seven show the uniserial manner of growth, though in only three cases have more than one chamber been added on that plan. This is a much larger proportion of shells taking on the *bigenerine* growth than occurs in *B. capreolus* from the same gatherings in which species such shells are exceedingly rare, not amounting to perhaps more than $\frac{1}{4}$ per cent.

(The majority of the specimens owing to their pointed oral extremities and the paucity of chambers in the uniserial series appear to show an affinity to *B. capreolus* rather than to *B. pennatula*. The distinction between the two species appears, however, to be purely arbitrary. Batsch's fig. C. is much nearer to d'Orbigny's Model of *B. capreolus* than Brady's figure of *B. capreolus* or Halkyard's specimens. Most of Halkyard's specimens would pass unquestioned as *Textularia carinata*, d'Orbigny, and are identical with the Maltese Miocene specimens which have always been assigned to *Textularia carinata*. The *spiroplectine* arrangement counts for very little except as regards taxonomy. It is probable that most *Textularidæ* are at times *spiroplectine* in their initial chambers.)

62. Bigenerina capreolus (d'Orbigny.)

Pl. II, figs. 10-13.

Vulvulina capreolus, d'Orb., 1826, Ann. Sci. Nat., vol. VII, p. 264, No. 1, pl. XI, figs. 5-8.
Schizophora capreolus, Schlumberger, Feuilles des Jeun. Nat., Aug. 1883, p. 117, pl. III, fig. 4, 4a.
Bigenerina capreolus, Brady, 1884, Chall. Rep., p. 372, pl. XLV, fig. 1-4.

The specimens placed under this name might in many cases be assigned to d'Orbigny's *Textularia carinata*, the reasons against that course being the frequent compression of the later chambers, which compression is always noticeable in *B. capreolus* before it commences adding on its uniserial chambers. In only two instances has the development been carried further and an attempt made to produce a medianly situated chamber. One of these specimens (Pl. II, fig. 10), which is of a weak form, has a narrow terminal chamber not placed on the median line but excentrically. Its orifice however is similar to that seen in a typical specimen.

In favour of considering the specimens as *T. carinata*, d'Orb. there is first, the fully developed carinate, and often

pectinate margin (Pl. II, fig. 11); second, the comparatively small backward curvature of the chambers (in fact in the weaker forms the sutures are almost at right angles to the longitudinal axis of the test); third, in some cases the great length of the test in proportion to its width (fig. 13.)

It will be seen from the drawings given here that the range of form is very great, still, the specimens have all certain features in common which mark them as variations of a single species, and besides this a perfect series can be made up which connects intimately the most dissimilar forms. Figure No. 13 is not drawn from a specimen found in the Blue Marl but from one found in the sandy beds (de la Harpe's Zone Superieur) to the north of St. Martin's Point, Biarritz, therefore figures 10-12 may be considered as covering the range of form of the Blue Marl specimens.

The spiral commencement of the test has been particularly noticed by Schlumberger, who describes the species under the name of *Schizophora capreolus*, d'Orb., thus reviving the genus created by Reuss. Though he gives the above specific name to his specimens I am inclined to the opinion, judging from the woodcut on page 22, and fig. 4, pl. 3, of his paper, that it is really Batsch's species *pennatula* which is under consideration. Schlumberger's description is as follows:— "Plasmostracum compressed at the extremities, swollen towards the middle; composed first: of five spiral chambers; second: of eleven alternate chambers; third: of four or five simple uniserial depressed chambers. The alternate chambers, as well as the earlier, are separated by prominent sutures which unite on the median line and terminate in a point at the margin. The uniserial chambers are separated by depressions." It will be noticed that this description will apply equally well to *B. capreolus* or to *B. pennatula*.

H. B. Brady also called attention to the peculiar manner of growth of the earlier portion of the test in *B. pennatula*. He however speaks of it as "occasional" and attributed it to "the extreme backward curvature of the earlier segments." It is evident in that case the chambers would be arranged in pairs surrounding the primordial segment and would not produce the spiral manner of growth plainly seen in Schlumberger's wood-cut and my section (Pl. II, fig. 12.)

This species is common at Biarritz.

(In spite of the foregoing arguments we should be inclined to refer all Halkyard's specimens to *Textularia carinata*, d'Orb. There is not a single specimen that could be unhesitatingly referred to *B. capreolus*.)

Sub-genus Siphogenerina, Schlumberger.

This sub-genus was founded by Schlumberger in 1883 for the reception of certain species which resemble *Bigenerina* in the arrangement of their chambers but which are furnished internally with a series of longitudinal median tubes, the tubes only existing in the uniserial portion of the test, and serving to connect the oral orifice of a chamber with the one immediately below it. Schlumberger describes the oral aperture as being, "Excentric, round, bordered by a slight raised rim, and opening alternately to the right and left of the axis." That description is too narrow to include the many varieties of aperture found in the sub-genus. I have noted myself 1—A produced phialine neck which is common in the Lagenidæ; 2—A large circular orifice surrounded by a raised rim; 3—A large oval orifice surrounded by a raised rim; 4—A narrow curved slit with a depressed margin, sometimes supplemented by scattered pores on the septal face of the segments. As regards the oral apertures of the biserial portion of the test, they are *textularian* or *bolivine*.

The first published drawing of a *bigenerine* shell with an internal tube is one given by Goës in "Reticularian Rhizopoda of the Caribbean Sea" (Stockholm, 1882). A figure given in this work (Plate V, fig. 166) plainly shows the internal tube, but Goës does not seem to have realized its significance or perhaps misinterpreted the microscopical image, as he refers later in "The Foraminifera of the U.S.S. Albatross" (1896) to the outlines of the tube as being "a couple of longitudinal folds on each segment." This form is given in the last mentioned memoir a new specific name, viz.:—*Sagrina pygmæa*. Goës however says that "It is with some hesitation" that he thus distinguishes it.

The following is a list of species which have an internal tube, and which are generally *bigenerine* in growth, though occasionally specimens are found which are not biserial at the commencement.

1.—*S. raphanus* Parker and Jones.
2.—*S. columellaris* Brady.
3.—*S. dimorpha* Parker & Jones.
4.—*S. striata* (Schwager).
5.—*S. calcarata* Berthelin.
6.—*S. pygmæa* Goës.
7.—*S. schlumbergerii* Millett.
8.—*S. ocracea* Schlumberger.
9.—*S. sulcata*, sp. n.
10.—*S. papillosa*, sp. n.
11.—*S. hexagona*, sp. n.

Of the above 11 species the first 6 have previously been assigned to the genus *Sagrina* but on account of tneir internal structure are transferred to *Siphogenerina*. The former genus is thus reduced to a very small one, but undoubtedly, to my own knowledge, *S. nodosa*, Parker & Jones, will still remain a member of it, as showing no internal tube, and having the early portion of the test formed as in *Uvigerina*.

[63. SAGRINA RAPHANUS, Parker & Jones.]

63A. SIPHOGENERINA RAPHANUS, (Parker & Jones.)

Uvigerina (*Sagrina*) *raphanus*, Parker & Jones, 1865, Phil. Trans., p. 364, pl. XVIII, figs. 16, 17.

Sagrina raphanus, Brady, 1884, Chall. Rep., vol. IX, p. 585, pl. LXXV, figs. 21-24.

The species is very rare in our gatherings, only two long slender specimens being found in gathering No. 2, 1893. The transverse sutures of these specimens are slightly recurved in the uniserial portion of the test, which is also slightly compressed. In this respect they resemble the compressed *Bigenerinæ*, viz., *B. capreolus*, and *B. pennatula*.

Schlumberger refers this species to the genus *Siphogenerina* under the name of *S. costata*, but it does not differ in any important respect from the specimens described by Messrs. Parker & Jones in 1865. The species is very variable in form ranging from long narrow examples with sharp, much elevated costæ to short, stout individuals with rounded longitudinal ribs. The earlier portion of the test is sometimes Textularian and sometimes Uvigerine, and even when biserial it often shows a sort of tendency to Uvigerine growth by the line of juncture of the two series of chambers being more or less oblique or twisted, generally towards the right.

By personal examination of some Australian specimens in my own collection I have noted the presence of a series of median internal tubes, but owing to the infiltration of the Biarritz specimens with calcite and pyrites I have not been able to observe in them a similar structure.

(These specimens if correctly identified should in our opinion be referred to *Sagrina raphanus* P. & J. but we are not satisfied as to their identity. They are much longer and narrower than any specimens of *S. raphanus* that we have ever seen, and there is no evidence of any Uvigerine commencement. We should have ascribed them with little hesitation to *Nodosaria obliqua*. (Linné.))

[64. Sagrina dimorpha, Parker & Jones.]

64a. Siphogenerina dimorpha, (Parker & Jones.)

Uvigerina (*Sagrina*) *dimorpha*, Parker & Jones, 1865, Phil. Trans., p. 363, pl. XVIII, fig. 18.

Sagrina dimorpha, Brady,, 1884, Chall. Rep., vol. IX, p. 582, pl. LXXVI, figs. 1-3.

A few typical examples collected from the upper horizons of the Marl. These specimens are not straight but curved like *Dentalina* and the earlier portion is biserial. The test is thin with very numerous and well-marked perforations. I have observed in one of these specimens the internal tube which is a characteristic of the sub-genus and which no doubt exists in the other individuals, but owing to their state of preservation I was not able to see it in them.

(The specimens are longer, thinner in the shell wall, and the cusps between the chambers are much less pronounced than in recent types, but in other features they agree tolerably well with *Sagrina dimorpha* P. & J.)

[65. Sagrina columellaris, Brady.]

65a. Siphogenerina columellaris, (Brady.)

Sagrina columellaris, Brady, 1881, Quart. Journ. Micr. Sci., vol. XXI, p. 64.

Sagrina columellaris, Brady, 1884, Chall. Rep., vol. IX, p. 581, pl. LXXV, figs. 15-17.

Very rare, only three small specimens found in gathering No. 3, 1893. The test is coarsely porous, has the usual series of internal tubes and the aperture is a curved slit with a raised border.

(These three specimens are certainly not identical with Brady's *Sagrina columellaris*. They differ in their extremely thin but coarsely perforated shell-wall. They appear to be closely allied to a little species which is not uncommon in tropical shallow waters, figured first by Goës (G. 1882, R.R.C.S. p. 79, pl. IX, figs. 165, 166) under the name "*Textularia pennatula* (Batsch) var. *aculeata* Ehrenberg, forma *Bigenerina*," and subsequently referred to by the same author (G. 1896. D.O.A., p. 51) under the name of *Sagrina pygmæa* Goës. The Biarritz specimens differ only in their circular section whereas the recent individuals usually become compressed in their later stages.)

66. SIPHOGENERINA SULCATA sp. nov.

Pl. VI, fig. 3.

Test elongate, biserial (?) at first, afterwards uniserial, acuminate at the commencement, circular in transverse section increasing in diameter to the final segment. Segments short and broad, ornamented with short thin costæ which are not continuous but are interrupted at the transverse sutures. Aperture a depressed slit, sometimes supplemented by scattered pores on the septal face. Length, .62mm.

Rare, only found in two gatherings, which, however, are separated by a considerable thickness of the Marl. Owing to lack of specimens and mal-conservation I have unfortunately been unable to verify beyond doubt whether the earlier portion of the shell is invariably biserial, but in the specimen of which a drawing is given this plan of growth seems to be followed, and is undoubtedly so in another specimen which was carefully broken up with a view of ascertaining the internal structure of the test. The results of this examination showed that the test commenced on the textularian plan, with five or six alternating chambers, followed by a linear series of five segments which were provided with internal median tubes. The number of chambers in the biserial portion of the test may be variable, and necessarily are so in the uniserial portion.

(This is closely allied if not identical with *Bigenerina conica* H-A. and E. (H-A. and E. 1908, etc., S.B. 1909, p. 329, pl. XVI), differing only in the absence of the external tubuli. Identical specimens occur frequently in the Australian Miocene of Filter Quarry, where they pass gradually into *B. conica*.)

[67. BIGENERINA CONICA, Heron-Allen & Earland.]

[*Bigenerina conica*, Heron-Allen & Earland, 1908, etc., S.B. 1909, p. 329, pl. XVI.]

67A. SIPHOGENERINA PAPILLOSA, sp. nov.

Pl. VI, fig. 4.

Test elongate, transverse section circular, increasing in diameter to the final segment, early portion biserial (?), afterwards uniserial. Segments short and broad, each one ornamented with one or two rows of papillæ. Aperture a curved slit. Length, .62mm.

The general characteristics of this species are similar to those of *S. sulcata*. It varies from the latter only in surface decoration, and perhaps in the absence of the supplemental orifices which occasionally appear in *S. sulcata*.

The lateral compression of the specimen figured on Plate VI. is accidental, the normal transverse section being round.

Rare in Gatherings 8 and 9, 1893.

(This is *B. conica* H-A. & E. The specimens are almost identical with the Selsey types, but somewhat smaller than the better developed Australian specimens.)

[68. Bigenerina selseyensis, Heron-Allen & Earland.]

[*Bigenerina selseyensis*, Heron-Allen & Earland, 1908, etc., S.B. 1909, p. 330, pl. XV, figs. 15-17.]

68a. Siphogenerina hexagona, sp. nov.

Pl. VI, fig. 5.

Test elongate, slightly compressed, early portion biserial, followed by a linear series of sub-globular chambers, aboral extremity of test generally furnished with a stout spine, surface decoration consisting of a raised hexagonal network. Aperture oval, large, with a raised rim. Length, .33mm.

This new form bears a strong resemblance to *S. schlumbergerii*. Millett, differing chiefly from that species in its surface ornamentation. I have observed the internal tube which is a feature of *Siphogenerina* in a specimen mounted in a transparent medium.

The species is rare and apparently only occurs in the lower portion of the Côte des Basques Marls.

(These are typical *B. selseyensis* H-A. & E.)

[69. Bigenerina selseyensis, Heron-Allen & Earland.]

69a. Siphogenerina calcarata, (Berthelin.)

Bigenerina calcarata, Berthelin, 1880, Mém. Soc. Géol., France, (3), vol. I, No. 5, p. 27, pl. I, figs. 14-16; and pl. II, figs. 2, a, b.

Sagrina calcarata, Chapman, 1898, Journ. Roy. Micr. Soc., p. 15, pl. II, fig. 14.

Rare and local, about a dozen specimens having been found in gatherings No. 8, 1893, whilst it is altogether absent from other gatherings. Millett in his "Foraminifera of the Malay Archipelago" (*) remarks that the aperture of *S. schlumbergerii* closely resembles that of *B. calcarata;* this is

* Journ. Roy. Micr. Soc., 1900, p. 7.

not the only resemblance between the two species, the internal structure being similar, as I have been able to verify from mounted specimens. In the latter species however the internal tube is of considerably greater diameter than in the former.

(These again are *B. selseyensis* H-A. & E. large and strongly developed, and not *B. calcarata*, Berthelin, the surface of which is smooth apart from the spines along the base of the chambers. Whilst it has been a matter of great satisfaction to us to note these records of the extended distribution of our species, we cannot help regretting that Halkyard should have sacrificed his priority of discovery and authorship of the species by postponing the publication of this paper.)

GENUS GAUDRYINA, d'Orbigny.

70. GAUDRYINA PUPOIDES, d'Orbigny.

Gaudryina pupoides, d'Orbigny, 1840, Mém. Soc. Géol. France (1) vol. IV, p. 44. pl. IV, figs. 22-24.
G. pupoides, Brady, 1884, Chall. Rep., p. 378, pl. XLVI, figs. 1-4.

This species is common in the Marl, and is generally elongated in form, resembling rather the fossil specimens found by d'Orbigny in the Paris Chalk than the recent ones of the "Challenger" and other collections.

71. GAUDRYINA RUGOSA, d'Orbigny.

Gaudryina rugosa, d'Orbigny, 1840, Mém. Soc. Géol., France (1), vol. IV, p. 44, pl. IV, figs. 20, 21.
G. rugosa, Brady, 1884, Chall. Rep., p. 381, pl. XLVI, figs. 14-16.

Another common species, more robust and of rougher texture than the last-named form, and further distinguished from it by being triangular in transverse section. The species is very generally distributed throughout the soft beds, but no specimens were found in the washings from No. 1 gathering 1893.

72. GAUDRYINA RUGOSA, var. DIFFORMIS, nov.

Pl. II, figs. 7-9.

This variety differs from its type species in the following particulars. It is smaller, more slender, with more compact chambers, the sutures are not excavated, but only represented by fine lines, the texture is comparatively smooth, and the later

portion of the shell assumes a quadrangular or pentagonal transverse section. In fact the variety bears the same relationship towards *G. rugosa* that Brady's *Clavulina angularis*, var. *difformis* does to its type form. The examples are rather rare but are well marked and form a distinct and easily recognisable variety. Length .57 to .73 mm.

(There seems to us to be very little reason for the creation of this variety.)

Genus Verneuilina, d'Orbigny.

73. Verneuilina tricarinata, d'Orbigny.

Verneuilina tricarinata, d'Orbigny, 1840, Mém. Soc. Géol., France (1), IV, p. 39, pl. IV, figs. 3, 4.

Frequent, persisting through the whole thickness of the Marl. The specimens found are variable in their proportions and range between such forms as d'Orbigny's original drawing and that figured by Terquem under the name of *V. elongata*.

74. Verneuilina spinulosa, Reuss.

Verneuilina spinulosa, Reuss, 1850, Denkschr, k. Ak. Wiss Wien, p. 374, pl. XLVII, fig. 12.

V. spinulosa, Brady, 1884, Chall. Rep., p. 384, pl. XLVII, figs. 1-3.

Very rare and minute in No. 7 gatherings only.

75. Verneuilina recurvata, sp. nov.

Plate III, fig. 7.

Test hyaline, formed of numerous chambers arranged regularly in three series round a longitudinal axis. The segments are long, narrow, and curved backwards, and each one is considerably longer than the preceding one of the same series. Lateral faces of the shell excavated. The dimensions of an average specimen are, length, .25 mm., breadth, .25 mm.

This new form is very easily distinguished from its nearest ally, *V. tricarinata*, d'Orb. Its chambers are much narrower and their septal faces are in the form of a high isosceles triangle rather than an equilateral one as in *V. tricarinata*. This last characteristic gives rise to the excavation of the lateral faces, which are hollow and curved inwards instead of being plane as in d'Orbigny's species. The specimen figured does not show the highest development of the backward curvature and

increase in length of the chambers, so I have added a dotted line in the drawing to show how far these features sometimes go. Such specimens however are generally very small and weak, and perhaps it would not be out of place to view this species as a weak starved form of *V. tricarinata*. However this may be it must be noted that no passage forms to fill up the gap have been found in the collections now under description.

(This is a very distinctive little variety of *V. tricarinata* d'Orb. It is worthy of note merely on account of the excessive concavity of the three faces of the shell; a slight degree of concavity is a normal variation of the genus. It is a minute hyaline isomorph of *V. variabilis* Brady. (Chall. Rep., 1884, p. 385, pl. XLVII, figs. 21-24.))

76. VERNEUILINA TRIQUETRA (Münster.)

Textularia triquetra, Münster, 1838, Roemer, Neues, Jahrb. für Min., etc., p. 384, pl. III, fig. 19.
Verneuilina triquetra, Brady, 1884, Chall. Rep., p. 383, pl. XLVII, figs. 18-20.

Extremely rare, only one small but typical specimen found in the large amount of material examined.

77. [UVIGERINA SELSEYENSIS, Heron-Allen & Earland.]
[*Uvigerina selseyensis*, Heron-Allen & Earland, 1908, etc., S.B. 1909, p. 437, pl. XVIII, figs. 1-3.]

GENUS TRITAXIA, Reuss.

77A. TRITAXIA DEHISCENS, sp. nov.

Pl. III, fig. 8.

Test vitreous, short, early portion tapering, nearly circular, tri-serial, afterwards becoming triangular and uniserial. Hinder margins of chambers projected outwards from sutures so as to leave them a free angular edge. Aperture consisting of a short produced neck with a phialine lip situated at the extremity of the final chamber. Length .35mm.

The characteristic of the shell which has earned for it its specific name is generally carried out to such an extent as to form a deep cavity on one of the lateral faces of the shell at the base of the last chamber. This little shell is closely allied to Brady's *Tritaxia lepida* and may be nothing more than a weak or local variety of it. The typical form however is not found at Biarritz, and the present one is rare. The earlier

triserial portion of the shell much resembles that of *Tritaxia caperata*, Brady.

(This is *Uvigerina selseyensis* H-A. & E. small, but quite typical.)

78. [Uvigerina selseyensis, Heron-Allen & Earland.]

78a. Tritaxia elongata, sp. nov.

Pl. III, fig. 9.

Test vitreous, elongate, parallel-sided, aboral end pointed, section triangular, angles rounded. Arrangement of chambers at first tri-serial, afterwards bi- and finally uniserial. Aperture, a short neck with phialine lip. Length .32 to .45 mm.

This form is frequent and might also be called common in our gatherings. One of its distinguishing features is the presence of hollows or excavations on the sutural lines, these are partly formed by the folding of the chamber-walls and partly by a tendency to backward prolongation of the sutural margin of the chamber, such as is seen in *Tritaxia dehiscens*. The drawing here given does not show this feature in its fullest development but represents an average specimen. In weak specimens the test is much elongated and is more circular in transverse section than in typical examples.

(This appears to be nothing more than an elongated form of *U. selseyensis* H-A. & E. in which the characteristic projecting and undercut chambers are narrower compared with the length of the shell. It is possible that the short and long forms may represent the dimorphism of the species.)

78b [Tritaxia lepida, Brady.]

[*Tritaxia lepida*, Brady, 1879, etc., RRC. 1881. p. 55.

T. lepida, Brady, 1884, FC. p. 389, pl. XLIX, fig. 12.]

Genus Clavulina, d'Orbigny.

79. Clavulina cylindrica, Hantken.

Clavulina cylindrica, Hantken, 1875, Mitth. Jahr. k. ung. geol. Anst., IV, pt. I, p. 18, pl. I, fig. 8.

C. cylindrica, Brady, 1884, Chall. Rep., p. 396, pl. XLVIII, figs. 32-38.

Frequent; the majority of the specimens are not large, though a few of respectable dimensions were found. The largest measures 1/7 inch in length.

80. [CLAVULINA ANGULARIS, d'Orbigny.]

[*Clavulina angularis*, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 268, No. 2, pl. XII, fig. 7.]

80A. CLAVULINA ULMENSIS (Gümbel).

Pl. III, figs. 4-6.

Tritaxia (?) *ulmensis*, Gümbel, 1871, Sitz. k. bayer. Ak. Wiss. Wien, vol. I, p. 63, pl. I, figs. 2a, b.

This species is a true *Clavulina*, being in fact the triangular form of *C. cylindrica*, as *C. angularis* d'Orb is the triangular form of the cylindrical *C. communis*. Gümbel's original figure, referred to above, represents a somewhat irregular specimen, with a much tapering initial portion. My specimens are more regular in form and more obtusely pointed at the aboral end of the test. Not rare in No. 2 Gathering, rare and small in Gathering No. 8. Absent in all others.

(Halkyard's specimens are identical with the large specimens of *C. angularis* so abundant in the Australian tertiary deposits, and which Chapman has proved (C. 1907, T. F. V. p. 29, 30. Pl. IV, figs. 71-73) to be the microspheric form of the normal megalospheric *C. angularis* with parallel sides. Gümbel's name and other synonyms for this pyramidal form must therefore be abandoned.)

81. CLAVULINA GAUDRYINOIDES, Fornasini.

Pl. III, figs. 1-3.

Clavulina gaudryinoides, Fornasini, 1885. Boll. Soc. Geol. Ital., vol. IV, p. 7, Tav. VI, figs. 3-9.

This species was discovered by Fornasini in the Miocene Marl of San Rufillo, near Bologna, Italy, and in his description he makes the following remarks: "The aperture varies in length and position, being found more or less distant from the interior margin of the last chamber, it varies also in degree of curvature, suggesting a passage to the linguiform aperture of *Valvulina*. Sometimes it presents itself furnished with a species of lip analogous to the small prolongation which is observed so frequently in *Clavulina communis*, d'Orb. Keeping account of the whole of the characters, the Textularian of which we are speaking is to be regarded as intermediate between the dimorphous variety of the *Valvulinæ* and the dimorphous variety of the *Textulariæ*. For palæontological

considerations and convenience of study, keeping in view the character of the incomplete alternation of the chambers I refer it to the genus *Clavulina* and name it *C. gaudryinoides.*"

My specimens found at Biarritz are numerous and differ somewhat from Fornasini's, being generally shorter and stouter. The oral aperture of my specimens consists of a round or oval orifice situated far from the sutural line, and has the edges rounded off inwards, instead of being provided with a lip as in the only figure given by Fornasini, which latter resembles closely the aperture of *Gaudryina pupoides* var. *chilostoma* as figured by Brady*, only differing in its position, being set further from the suture.

In my opinion Fornasini would have done better to refer his specimens to the genus *Gaudryina*, as, according to his own illustrated figures, the aperture is more like that of *Gaudryina*, and besides most of his figures show a distinct and sometimes very regular biserial plan of growth following the triserial portion of the test. The biserial chambers are followed by an irregular series disposed somewhat in the manner of the chambers of *Pleurostomella subnodosa*, Reuss. This uniserial portion never assumes the regularity of that observable in *Clavulina communis*, d'Orb.

In the event of it being thought advisable to transfer the form under discussion to the genus *Gaudryina* I would suggest the specific appellation "*trimorpha*" in allusion to its trimorphic growth.

Common in the lower half of the Marl, less frequent and smaller in the upper portion.

(Fornasini's figures cover a wide range of forms, and the Halkyard specimens agree generally, though they are as a whole of a shorter and less elongated growth, but they present a very wide range while at the same time they are evidently related. We are inclined to agree with Halkyard that the specimens would be better referred to *Gaudryina* than to *Clavulina*, but Fornasini's specific name must of course be retained and the specimens known as *Gaudryina gaudryinoides* (Fornasini.))

82. Clavulina parisiensis, d'Orbigny.

Clavulina parisiensis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 268, No. 3.
C. parisiensis, Brady, 1884, Chall. Rep., p. 395, pl. XLVIII, figs. 14-18.

* Chall. Rep. 1884, pl. XLVI, Fig. 5.

Not uncommon, but small and weak.

(The state of preservation of most of the specimens is so poor that their identification is more or less doubtful.)

83. CLAVULINA COMMUNIS, d'Orbigny.

Clavulina communis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 268, No. 4.
C. communis, Brady, 1884, Chall. Rep., p. 394, pl. XLVIII, figs. 1-13.

Small and rare.

SUB-FAMILY BULIMININÆ.

GENUS VIRGULINA, d'Orbigny.

84. VIRGULINA SCHREIBERSIANA, Czjzek.

Virgulina schreibersiana, Czjzek, 1848, Haidinger's Nat. Abh., vol. II, p. 147, pl. XIII, figs. 18-21.
V. schreibersiana, Brady, 1884, Chall. Rep., p. 414, pl. LII, figs. 1-3.

Common throughout the whole extent of the Marl. The specimens are typical and vary only to a slight extent.

(A very fine series of specimens and abnormally large.)

84a. [VIRGULINA SUBSQUAMOSA, Egger.]

[*Virgulina subsquamosa*, Egger, 1857, MSO. p. 295, pl. xii. figs. 19-21.
V. subsquamosa, Brady, 1884, FC. p. 415, pl. LII. figs. 7-11.]

85. VIRGULINA LINEATA, sp. nov.

Pl. VIII, fig. 5.

Test elongate, slightly compressed, lateral edges rounded, tapering at first, afterwards sub-cylindrical. Segments inflated, rather elongated, with tendency in later chambers to show inferior margins overlapping and free. Surface ornamentation low longitudinal costæ which are not continuous but each confined to its own segment. Length .45 mm.

There is really not much to be said about this form as the description and drawing given show its distinguishing characteristics, but attention may be drawn to its affinity on one hand to *Bolivina karreriana*, Brady, and on the other to *Virgulina schreibersiana*, Czjzek. As only one specimen has been found

it must be understood that I do not absolutely insist upon its being an unrecorded form, but in regard to its relationship to *B. karreriana* I would wish to remark that no specimens of that species have been found in the numerous collections which I have made from the Biarritz Marl, therefore it is not likely to be an aberrant specimen of that species, which may be considered as entirely absent from these beds. On the other side it must be admitted that the specimen under consideration is not a well developed one, as witness the small dimensions, the weak elongated aperture and the undecided setting-on of the last two chambers. All these points indicate a starved condition and an unsuitable habitat, which it is to be feared that my drawing does not emphasize sufficiently. This specimen has been lost since writing above.

(The type specimen has not been found. Judging by the figure this would appear to be an abnormal specimen of *Bolivina karreriana* Brady.)

Genus Bulimina, d'Orbigny.

86. Bulimina inflata, Seguenza.

Bulimina inflata, Seguenza, 1862, Atti Accad. Gioenia Sci. Nat. (2), vol. XVIII, p. 109, pl. I, fig. 10.
B. inflata, Brady, 1884, Chall. Rep., p. 406, pl. LI, figs. 10-13.

Small specimens occur, frequently as a rule, though in Gathering No. 5 only one specimen was noticed, and in No. 6 the species was absent.

86a. [Bulimina fusiformis, Williamson.]

[*Bulimina pupoides*, var. *fusiformis*, Williamson, 1858, RFGB. p. 63, pl. v. figs. 129, 130.
B. fusiformis, Millett, 1898, etc., FM. 1900, p. 275, pl. II, fig. 2.]

87. Bulimina buchiana, d'Orbigny.

Bulimina buchiana, d'Orbigny, 1846, Foram. Fossiles de Vienne, p. 186, pl. XI, figs. 15-18.
B. buchiana, Brady, 1884, Chall. Rep., p. 407, pl. LI, figs. 18, 19.

Small specimens are rather more frequent than of the last species but are not found in Gathering No. 2. In some material collected on the sands to the north of St. Martin's Pt. ("Zone Superieur" of de la Harpe) five specimens were found.

88. BULIMINA DECLIVIS, Reuss.

Bulimina declivis, Reuss, 1863 (1864), Sitz. k. Ak. Wiss. Wien, vol. XLVIII, (1), p. 55, pl. VI, fig. 70; and pl. VII, fig. 71.
B. declivis, Brady, 1884. Chall. Rep. p. 404, pl. L, figs. 19, a, b.

This species is rather rare and seems to be confined to the upper half of the Marl beds.

(The identification appears to be hardly satisfactory in view of the fact that the sutural lines are flush and hardly visible, whereas Reuss describes his species as having inflated (gewölbten) chambers and small but depressed sutures. On a type slide are some specimens recorded under the name *B. subteres*, not satisfactory as examples of that species but intermediate between *B. subteres*, Brady, and *B. declivis*.)

89. BULIMINA PUPOIDES, d'Orbigny.

Bulimina pupoides, d'Orbigny, 1864, Foram. Fossiles de Vienne, p. 185, pl. XI, figs. 11, 12.
B. pupoides, Brady, 1884, Chall. Rep., p. 400, pl. L, fig. 15.

Specimens very rare and small.

89A. [BULIMINA PRESLI, Reuss.]

[*Bulimina presli*, Reuss, 1845-6, VBK. p. 38, pl. xiii, fig. 72.
B. presli, Heron-Allen & Earland, 1908, etc., SB. 1910, p. 408.]

90. BULIMINA PYRULA, d'Orbigny.

Bulimina pyrula, d'Orbigny, 1846, Foram. Fossiles de Vienne, p. 184, pl. XI, figs. 9, 10.
B. pyrula, Brady, 1884, Chall. Rep., p. 399, pl. L, figs. 7-10.

Not rare and very generally distributed.

91. BULIMINA OVATA, d'Orbigny.

Bulimina ovata, d'Orbigny, 1846, Foram. Fossiles de Vienne, p. 185, pl. XI, figs. 13, 14.
B. ovata, Brady, 1884, Chall. Rep., p. 400, pl. L., figs. 13, a, b.

Specimens typical and rather more frequent than *B. pyrula*.

92. BULIMINA ELONGATA, d'Orbigny.

Bulimina elongata, d'Orbigny, 1826, Ann. Sci. Nat., VII, p. 269, No. 9.

B. elongata, Brady, 1884, Chall. Rep., p. 401, pl. L, figs. 1 and 2 (?).

Very rare and only found in Gathering No. 7.

92A. [Bulimina elegantissima, d'Orbigny.]

[*Bulimina elegantissima*, d'Orbigny, 1839, FAM. p. 51, pl. VII, figs. 13, 14.
Bulimina elegantissima, Brady, 1884, FC. p. 402, pl. L, figs. 20-22.]

Genus Bolivina, d'Orbigny.

93. Bolivina robusta, Brady.

Bolivina robusta, Brady, 1881, Quart. Journ. Micr. Soc., vol. XXI, p. 57.
B. robusta, Brady, 1884, Chall. Rep., p. 421, pl. LIII, figs. 7-9.

Frequent, but small, in Gatherings 3, 4, and 9, absent in others. The specimens are not so stout and robust as Brady's and incline towards *B. dilatata*, Reuss, in the setting-on of the chambers and the tendency to sharpness of the peripheral margin, but there can be no hesitation in assigning them to Brady's species.

94. Bolivina nobilis, Hantken.

Bolivina nobilis, Hantken, 1875, Mitth. Jahrb. k. ungar. geol. Anst., vol. IV, pt. I, p. 65, pl. XV, fig. 4
B. nobilis, Brady, 1884, Chall. Rep., p. 424, pl. LIII, fig. 14, 15.

This species is plentiful throughout the beds and sometimes show a tendency towards *B. œnariensis*, (Costa), the specimens becoming flatter, and the periphery sharper than in the type, whilst the longitudinal striæ becomes less numerous and sometimes nearly absent.

(We do not see any evidence of the variation in the direction of *B. œnariensis*. The specimens are all remarkably fine and typical. A separate unnamed slide however occurs in the collection labelled "intermediate specimens" and these are no doubt those referred to in the text. Taxonomically we think they are referable to *B. œnariensis*, but all exhibit a more or less prominent costation on the early chambers linking them with *B. nobilis*.)

94A. [BOLIVINA VARIABILIS, (Williamson.)]

[*Textularia variabilis* (typica), Williamson, 1858, RFGB. p. 76, pl. vi, figs. 162, 163 (incorrectly numbered 161, 162 on the plate).
Bolivina variabilis, Heron-Allen & Earland, 1914, etc., FKA, 1915, p. 647.]

95. BOLIVINA ÆNARIENSIS, (Costa.)

Brizalina œnariensis, Costa, 1856, Atti. Accad. Pontaniana, vol. VII, (2), p. 297, pl. XV, figs. 1 and 2.
Bolivina œnariensis, Brady, 1884, Chall. Rep., p. 423, pl. LIII, figs. 10, 11.

Frequent in most of the gatherings but absent from No. 7 and rare in Nos. 8 and 9, thus predominating in the upper portion of the beds. The examples are fine and well-marked.

(A considerable percentage of the specimens show a tendency to an axial twist, which is not uncommon in the genus.)

96. BOLIVINA PUNCTATA, d'Orbigny.

Bolivina punctata, d'Orbigny, 1839, Voyage Amér. Mérid., vol. V (5), "Foraminifères," p. 63, pl. VIII, fig. 10-12.
B. punctata, Brady, 1884, Chall. Rep., p. 417, pl. LII, figs. 18, 19.

Small and rather rare.

96A. [BOLIVINA LOBATA, Brady.]

[*Bolivina lobata*, Brady, 1879, etc., RRC. 1881, p. 58.
B. lobata, Brady, 1884, FC. p. 425, pl. LIII, figs. 22, 23.]

97. BOLIVINA INTERMEDIA, sp. nov.

Pl. III, fig. 10.

Test tapering, rarely parallel-sided, somewhat depressed, rounded at aboral extremity, thickest in the centre on the longitudinal axis, periphery rounded; segments few, and large, the last being more depressed and having a sharper periphery than the previous ones. Sutures sinuous, aperture large, occupying nearly the whole of the superior extremity of the last chamber. Sutures oblique, regularly curved at first, afterwards sinuate. Length, .3 to .45 mm.

This species is a connecting link between *B. punctata* d'Orbigny and *B. limbata*, Brady. It resembles the first in its

regularity of growth and shell texture, and the latter in its depressed transverse section and sinuous sutures, and differs from both in its greater breadth. It is rather rare but widely distributed in our gatherings, having been found in them all excepting No. 1, 1893.

(This little form appears to us to be nearer to *B. textilarioides*, Reuss, than to *B. limbata*.)

98. Bolivina dilatata, Reuss.

Bolivina dilatata, Reuss, 1850, Denkschr. k. Ak. Wiss. Wien, vol.I, p. 381, pl. XLVIII, fig. 15.
B. dilatata, Brady, 1884, Chall. Rep., p. 418, pl. LII, figs. 20, 21.

Frequent and persistent. Specimens finest at the top of the beds, gradually weakening towards the base.

(All the specimens are of an elongate type approaching *B. ænariensis*.)

99. Bolivina beyrichi, Reuss.

Bolivina beyrichi, Reuss, 1851, Zeitschr. deutsch. geol. Ges., III, p. 83, pl. VI, fig. 51.
B. beyrichi, Brady, 1884, Chall. Rep., p. 422, pl. LIII, fig. 1.

Rare and small, approaching *B. dilatata* in having long narrow segments, and very much compressed. Its variety *alata*, Seguenza, occurs frequently in Gathering No. 1. and is still nearer *B. dilatata* in the form and setting-on of the chambers, though easily distinguishable by its carinate and pectinate margins. Neither form is found in the lower marls.

100. Bolivina plicata, d'Orbigny.

Bolivina plicata, d'Orbigny, 1839, Voyage Amér. Mérid. vol. V (5), "Foraminifères," p. 62, pl. VIII, figs. 4-7.
B. plicata, Brady, 1870, Ann. Mag. Nat. Hist., (4), vol. VI, p. 302, pl. XII, fig. 7a, b.

Frequent, small but typical, and well preserved. Wanting in Gatherings 5 and 6.

101. Bolivina reticulata, Hantken.

Bolivina reticulata, Hantken, 1875, Mitth. Jahrb. k. ungar. geol. Anst., vol. IV, pt. I, p. 65, pl. XV, fig. 6.
B. reticulata, Brady, 1884, Chall. Rep., p. 426, pl. LIII, figs. 30, 31.

Typical examples frequent. The species however is at its best at the top of the Marl where there is very little sand mixed with the clay. This fact seems to show that the species flourishes better on an oozy bottom.

102. BOLIVINA TORTUOSA, Brady.

Bolivina tortuosa, Brady, 1881, Quart. Journ. Micr. Soc., vol. XXI, p. 57; and 1884, Chall Rep., p. 420, pl. LII, figs. 31-34.

Not so frequent as the last species but still cannot be called rare. Some of the specimens are fine and strongly-built, whilst others are small, delicate, and more regular in the setting-on of the segments.

(The degree of axial curvature is very variable in the specimens, in some cases practically non-existent.)

GENUS PLEUROSTOMELLA, Reuss.

103. PLEUROSTOMELLA ALTERNANS, Schwager.

Pleurostomella alternans, Schwager, 1866. Novara-Exped., Geol. Theil II, p. 238, pl. VI, figs. 79, 80.
P. alternans, Brady, 1884, Chall. Rep., p. 412, pl. LI, figs. 22, 23.

Rare, occurring only in Gatherings No. 6 and 7.

(The specimens are of a very short and broad type.)

SUB-FAMILY CASSIDULININÆ.

GENUS CASSIDULINA, d'Orbigny.

104. CASSIDULINA SUBGLOBOSA, Brady.

Cassidulina subglobosa, Brady, 1881, Quart. Journ. Micr. Soc. vol. XXI, p. 60; and 1884, Chall. Rep., p. 430, pl. LIV, figs. 17a, b, c.

Not rare, but the specimens are small though well-formed.

105. CASSIDULINA LÆVIGATA, d'Orbigny.

Cassidulina lævigata, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 282, pl. VI, figs. 4-5.
C. lævigata, Brady, 1884, Chall. Rep., p. 428, pl. LIV, figs. 1-3.

The specimens are small, of a somewhat thick type, without marginal carina.

FAMILY CHILOSTOMELLIDÆ.

Genus Chilostomella, Reuss.

106. Chilostomella ovoidea, Reuss.

Chilostomella ovoidea, Reuss, 1850, Denkschr. k. Ak. Wiss. Wien, vol. I, p. 380, pl. XLVIII, fig. 12.
C. ovoidea, Brady, 1884, Chall. Rep., p. 436, pl. LV, figs. 12-23.

Rare, but seemingly persistent from top to bottom of the Marls.

FAMILY LAGENIDÆ.

SUB-FAMILY LAGENINÆ.

Genus Lagena, Walker & Boys.

107. Lagena lævis, (Montagu.)

Vermiculum læve, Montagu, 1803, Testac. Brit., p. 524.
Lagena lævis, Brady, 1884, Chall. Rep., p. 455, pl. LVI, figs. 7-14, and 30.

Frequent, generally distributed, and very variable in form.

(The majority of the specimens are of the globular type with produced necks, but inasmuch as nearly all the specimens are represented by calcite casts, their specific identity in many cases is more or less uncertain.)

108. Lagena globosa, (Montagu.)

Serpula (Lagena) lævis globosa, Walker & Boys, 1784, Test. Min. Rar., etc., p. 3, pl. I, fig. 8.
Vermiculum globosum, Montagu, 1803, Testac. Brit., p. 523.
Lagena globosa, Brady, 1884, Chall. Rep., p. 452, pl. LVI, figs. 1-3.

Frequent, and generally distributed. The finest specimens are nearly all provided with an entosolenian tube, and a projecting basal tube at the other extremity of the test. As regards the specimens with radiate apertures it must at all times be very difficult if not impossible to say whether such tests are to be referred to *Lagena*, or are the primordial segments of other genera of the same family. In other words, to say whether the shell has arrived at its adult condition, or whether it will not add to itself additional chambers.

(On one of the type slides is an unnamed specimen, a calcite cast which was probably assigned by Halkyard to this species, but which possessing a large apical aperture and

recurved basal tube, may possibly have been *L. ampulla-distoma*, Rymer Jones.)

108A. [LAGENA AMPULLA-DISTOMA, Rymer-Jones.]

[*Lagena vulgaris*, var. *ampulla-distoma*, Ry.-Jones, 1872, LJS, p. 63, pl. xix, fig. 52.
L. ampulla-distoma, Heron-Allen & Earland, 1914, etc., FKA. 1915, p. 655.]

109. LAGENA OVUM, (Ehrenberg.)

Miliola ovum, Ehrenberg, 1843, Bericht k. preuss. Wiss. Berlin, p. 166; 1854, Mikrogeol, pl. XXIII, fig. 2.
Lagena ovum, Brady, 1884, Chall. Rep., p. 454, pl. LVI, fig. 5.

Extremely rare, one specimen only found in the whole of the material examined.

(The specimen is a cast, and quite possibly an oval *L. lævis*, with the neck absent.)

110. LAGENA GRACILLIMA, (Seguenza.)

Amphorina gracillima, Seguenza, 1862, Foram. monotal. miocen. Messina, p. 51, pl. I, fig. 37.
Lagena gracillima, Brady, 1884, Chall. Rep., p. 456, pl. LVI, figs. 19-28.

Very rare, only found in the gatherings from the lowest portion of the beds.

(The three specimens are all casts and it is doubtful whether they should be referred to this species—the one from Gathering 7 is more probably *L. apiculata*, Reuss, and the two from Gathering 8 probably detached chambers of *Nodosaria pyrula*, d'Orb.)

111. LAGENA HISPIDA, Reuss.

Lagena hispida, Reuss, 1858, Zeitschr. deutsch, geol. Ges., vol. X, p. 434.
L. hispida, Brady, 1884, Chall. Rep., p. 459, pl. LVII, figs. 1-4; and pl. LIX, figs. 2 and 5.

Rather rare, but widely distributed.

(The specimens are nearly all casts and the majority, both in their globular shape and short thick neck, and the coarseness of their external markings are more nearly allied to *L. aspera*, Reuss, than to *L. hispida*, which is usually of oval form.)

112. Lagena aspera, Reuss.

Lagena aspera, Reuss, 1861 (1862), Sitz k. Ak. Wiss Wien. vol. XLIV, p. 305, pl. I, fig. 5.
L. aspera, Brady, 1884, Chall. Rep., p. 457, pl. LVII, figs. 7-12.

Rare and small.

(The specimens are very slightly different from those separated under the name *L. hispida*.)

113. Lagena striata (d'Orbigny.)

Oolina striata, d'Orbigny, 1839, Voyage Amér. Merid, vol. V, pt. 5, "Foraminifères," p. 21, pl. V, fig. 12.
Lagena striata, Brady, 1884, Chall. Rep., p. 460, pl. LVII, figs. 22, 24, 28, 30.

Frequent and variable in contour as well as in strength and relative closeness of the striæ. In the larger and globular specimens the striæ are often broken up at the extreme base of the shell, so that that portion is covered with small tubercles.

(Many of the specimens might with reason be assigned to weak *L. sulcata*. The tuberculate base referred to is of constant occurrence in both *L. striata* and *L. sulcata* and merely evidence of growth in deep, still water. It reaches an abnormal development in the form of short spines in the large fossils from the Miocene of Naparina, Trinidad, and in the deeper waters of the North Sea.)

114. Lagena sulcata (Walker & Jacob.)

Serpula (*Lagena*) *sulcata*, Walker & Jacob, 1798. In Kanmacher's edn. of Adam's Essays Microsc., p. 634, pl. XIV, fig. 5.
Lagena sulcata, Brady, 1884, Chall. Rep., p. 462, pl. LVII, figs. 23, 26, 33, 34; and pl. LVIII, figs. 4, 17, 18, etc.

Frequent. The specimens are slender in form with few thin costæ, and are well represented by the form figured by Brady on pl. LVIII, fig. 18 (loc. cit.) The variety *interrupta*, Will. is very rarely met with, and as might be expected, the costæ are weaker and not so elevated as in the type species.

(Nearly all the specimens, in the abnormal development of the costæ, give evidence of growth in deep, still water.)

114a. [Lagena quinquelatera, Brady.]

[*Lagena quinquelatera*, Brady, 1879, etc., RRC. 1881, p. 60.
L. quinquelatera, Brady, 1884, FC. p. 484, pl. LXI, figs. 15, 16.]

115. LAGENA ACUTICOSTA, Reuss.

Lagena acuticosta, Reuss, 1861, Sitz. k. Ak. Wiss. Wien, vol. XLIV, (1), p. 305, pl. I, fig. 4.
L. acuticosta, Brady, 1884, Chall. Rep., p. 464, pl. LVII, figs. 31, 32; and pl. LVIII, figs. 20 and (?) 21.

Very rare, but typical sub-globular with strong costæ.

(The two specimens should we think be referred to *L. costata*, (Will.).)

116. LAGENA WILLIAMSONI (Alcock.)

Entosolenia williamsoni, Alcock, 1865, Proc. Lit. Phil. Soc. Manchester, vol. IV, p. 193.
Lagena williamsoni, Balkwill & Wright, 1885, Trans. Roy. Irish Acad. vol. XXVIII (Sci.), p. 339, pl. XIV, figs. 6-8.

Common. The specimens are not always typical, the hexagonal marking of the neck which is characteristic of the species being in some cases absent, or often reduced to the merest trace. Under these conditions the specimens are hardly distinguishable from *L. acuticosta*, Reuss, as the costæ are few in number and of comparatively great elevation. The shells are, however, pyriform and the grooves between the costæ are sectionally an arc of a circle. The costæ do not run into one another at the base of the shell, but abut upon the circumference of a small raised ring. When the hexagonal pitting of the neck can be discerned the specimens undoubtedly belong to Alcock's species, and in the other cases the difference is so slight and so filled up by innumerable inseparable gradations that there is no need to insist upon the presence of that feature. The best published figure of this species is that given by Balkwill & Wright, which is an excellent one. Their figure shows that the number of the costæ is about eighteen. My examples have from 8 to 13.

(A large proportion of the specimens are absolutely destitute of the hexagonal markings round the base of the neck which form the characteristic feature of the species, and should therefore be ascribed without hesitation to the earlier named *L. acuticosta* Reuss.)

116A. [LAGENA STRIATO-PUNCTATA, Parker & Jones]

[*Lagena sulcata* var. *striato-punctata*, Parker & Jones, 1865, NAAF, p. 350, pl. XIII, figs. 25-27.
Lagena sulcata, var. *striato-punctata*, Brady, 1884, FC. p. 468, pl. LVIII, figs. 37, 40.

117. Lagena striato-punctata, Parker & Jones, var. caudata, nov.

Pl. III, fig. 12a, b.

Lagena sulcata var. *striato-punctata*, Parker & Jones, 1865, Phil. Trans., vol. CLV., p. 350, pl. XIII, figs. 25-27.

This variety differs from the type in having the costæ prolonged backwards beyond the base of the test which is further ornamented by the addition of a central basal spine. Specimens are frequent in Gatherings Nos. 4 and 5, and the type is altogether absent. (See 116a. H-A. & E.) The drawing given here shows the basal spine at its fullest development.

(This is a very distinctive variety, and occurs with its features still more strongly accentuated in some of the Australian Tertiaries. The costæ in some Australian specimens project as recurved basal claws, approaching *L. plumigera* Brady.)

118. Lagena flexicollis, sp. nov.

Pl. III, fig. 11.

Test elongate, cylindrical, ornamented with about eighteen longitudinal rows of minute perforations; the neck of the test furrowed by three deep grooves; the base of the neck less deeply furrowed by six to nine grooves. Base of test flat, with notched circumference. Length, .38 mm.

This form is a near ally of *L. striato-punctata*, showing its relationship by the rows of perforations, and also by the notching of the base and the furrowing of the lower part of the neck, which are evidently the remains of the costæ which ornament Parker's & Jones' species. The species is rare, only three examples being found in our collections, these occurring in Gatherings Nos. 6 and 9.

(The three specimens are all calcite casts, and we have little doubt that they should be referred to *L. feildeniana*, Brady, the lines of perforation following what have apparently been the depressions between sulci in the original shell, and not perforating the sulci as in *L. striato-punctata*. The asymetrical position of the neck is a feature of frequent occurrence in this group of the *Lagenæ*. Cf. Sidebottom's figures of *L. striato-punctata*. (S. 1912 S.W.P. pl. XVI, figs. 7, 8, 10.))

119. Lagena hexagona (Williamson.)

Entosolenia squamosa, var. *hexagona*, Williamson, 1848, Ann. Mag. Nat. Hist. (2), vol. I, p. 20, pl. II, fig. 23.

Lagena hexagona, Brady, 1884, Chall. Rep., p. 472, pl. LVIII, figs. 32, 33.

The typical form with regular raised hexagonal reticulated ornament is rare, and is found only in the upper half of the Marl. In our collections, on the one hand it merges into *L. melo*, d'Orb, and on the other the reticulation becomes irregular, the meshes taking on a square, and also pentagonal form over a large portion of the shell, so merging into *L. reticulata* (Macgillivray.)

(We do not see any evidence of affinity with *L. melo* in Halkyard's specimens, which are all of a small type and resembling Williamson's varieties *scalariformis* and *catenulata*.)

120. LAGENA RETICULATA (Macgillivray.)

Lagenula reticulata, Macgillivray, 1843, Hist. Moll. Anim. Aberdeen, etc., p. 38.
Lagena squamosa, P. J. & B., 1865, Foram. of the Crag, pt. I. p. 39, pl. IV, fig. 7.
L. reticulata, T. R. Jones, 1895, Foram. of the Crag, pt. II. p. 195.

This species is more frequent than the last named, and is distinguished by the irregular reticulation of its surface ornamentation. As regards the size of the test and reticulation, as well as in form, there is no difference between the two species in the Biarritz examples.

(The majority of specimens should, we think, be referred to *L. hexagona* (Will.).)

121. LAGENA MELO (d'Orbigny.)

Oolina melo, d'Orbigny, 1839, Voy. Amér. Mérid. vol. V, pt. 5. "Foraminifères," p. 20, pl. V, fig. 9.
Very rare and small.

(The specimens must be referred to *L. hexagona* (Will.). They are quite unlike d'Orbigny's type, which is of very rare occurrence, and in which the transverse costæ are set regularly in parallel bars across the longitudinal sulci.)

122. LAGENA LÆVIGATA (Reuss.)

Fissurina lævigata, Reuss, 1850, Denkschr. k. Ak. Wiss. Wien. vol. I, p. 366, pl. XLVI, fig. 1.
Lagena lævigata, Brady, 1884, Chall. Rep., p. 473, p. CXIV, figs. 8a, b.

Small and very rare.

123. LAGENA MARGINATA (Walker & Boys.)

Serpula (*Lagena*) *marginata*, Walker & Boys, 1784, Test. Min., p. 2, pl. I, fig. 7.
Lagena marginata, Brady, 1884, Chall. Rep., p. 476, pl. LIX, figs. 21-23.

Frequent and typical but not of large dimensions.

(A large proportion of the specimens are of the well marked variety *Fissurina carinata* Reuss figured by von Schlicht (R. 1870 F.S.P. p. 469 and S. 1870 F.S.P. pl. V, figs. 1-3.) and named by Silvestri *Fissurina schlichti*. Included on the same slide are a few specimens which should be referred to *L. orbignyana* (Seguenza) and *L. fasciata* (Egger.))

124. LAGENA MARGINATA, var. INÆQUILATERALIS, J. Wright.

Lagena marginata, var. *inæquilateralis*, J. Wright, 1886, Proc. Belfast Nat. Field Club, 1884-5, App. 1886, p. 321, pl. XXVI, figs. 10a, b, c.

Extremely rare, only one specimen found.

(The single specimen is of the weakest character and hardly worth separating.)

125. LAGENA RADIATO-MARGINATA, Parker & Jones.

Lagena radiato-marginata, Parker & Jones, 1865, Phil. Trans., p. 355, pl. XVIII, figs. 3a, b.
L. radiato-marginata, Brady, 1884, Chall. Rep., p. 481, pl. LXI, figs. 8, 9.

Very rare, three specimens found in Gathering No. 3. These examples ought rather to be classed as a variety of *L. orbignyana* than one of *L. marginata*, seeing that besides the marginal keel they also possess two narrower parallel ones.

(The specimens cannot by any latitude of identification be referred to Parker & Jones' species which is a most characteristic type. They are merely a variety of *L. orbignyana* characterized by the existence of radiating grooves extending from a central boss of clear shell substance, in other words, an ornate modification of Wright's variety *walleriana* (W. 1891. S.W.I. p. 481, pl. XX, fig. 8.). The little test figured by Sidebottom (S. 1912 L.S.P. p. 417, pl. XIX, fig. 20) *L. orbignyana* var. *curvicostata* is identical in the character of the superficial markings, but differs in the recurving of the carinæ at the base. In the Biarritz specimens the carina is continuous as in typical *L. orbignyana*.)

126. [LAGENA BICARINATA (Terquem.)]

[*Fissurina bicarinata*, Terquem, 1882, Foram. Eocène de Paris, p. 31, pl. I (IX), fig. 24a, b.
Lagena bicarinata, Balkwill & Millett, 1884, Foram. of Galway, p. 82, pl. II, fig. 4; and pl. III, fig. 9.]

126A. LAGENA QUADRATA (Williamson.)

Entosolenia marginata, var. *quadrata*, Williamson, 1858, Rec. Brit. Foram., p. 11, pl. I, figs. 27, 28.
Lagena quadrata, Brady, 1884, Chall. Rep., p. 475, pl. LIX, figs. 3 and 16; pl. LX, fig. 5.

Very rare and small.

(The specimens should be referred to *L. bicarinata* (Terquem).)

127. LAGENA QUADRANGULARIS, Brady.

Lagena quadrangularis, Brady, 1884, Chall. Rep., p. 483, pl. CXIV, fig. 11a, b.

Very rare. The specimens found are not so elongate as Brady's figure; one is provided with a long neck and is nearly circular on the lateral face, which has in the centre a well-defined ring of clear shell substance which, however, is not raised above the surface.

(These specimens in our opinion should also be allotted to *L. bicarinata* (Terquem.). The long-necked specimen referred to in the text may be compared with the similar abnormal form figured by Sidebottom (S. 1912. L.S.P. p. 419, pl. XX, fig. 1.))

128. LAGENA ORBIGNYANA (Seguenza.)

Fissurina orbignyana, Seguenza, 1862, Foram. monotal. miocen. Messina, p. 66, pl. II, figs. 25, 26.
Lagena orbignyana, Brady, 1884, Chall. Rep., p. 484, pl. LIX, figs. 1, 18, 24-26. Winged variety fig. 20.

Frequent. Amongst the deviations from type found were a few specimens showing faint reticulation of the surface, also faint striations, and signs of pittings. None of these markings were sufficiently well-marked to warrant the examples being noted as distinct varieties, but are interesting as being links with *L. clathrata* Brady, *L. lacunata* Burrows & Holland, and *L. squamosa* (Montagu). One specimen of trigonal form was also noted.

128A. [LAGENA ORBIGNYANA, var. SELSEYENSIS, Heron-Allen and Earland.]

[*Lagena orbignyana*, var. *selseyensis*, Heron-Allen & Earland, 1908, etc., SB. 1909, p. 426, pl. XVII, figs. 1, 2.]

129. LAGENA ORBIGNYANA, var. WALLERIANA, J. Wright.

Lagena orbignyana, var. *walleriana*, J. Wright, 1891, Proc. Roy. Irish Acad., Ser. 3, vol. I, No. 4, p. 481, pl. XX, fig. 8a, b.

Very rare, occurring only in the west beds. The examples found are similar to those collected from the St. Erth clay by Millett, in which the central boss is represented by a small raised ring.

130. LAGENA CLATHRATA, Brady.

Lagena clathrata, Brady, 1884, Chall. Rep. 485, pl. LX, fig. 4.

Very rare and small, found only in Gathering No. 1.

131. LAGENA PUNCTATA (Seguenza.)

Fissurina punctata, Seguenza, 1880. Atti. R. Acc. Lincei, (3), vol. VI, p. 136, pl. XIII, fig. 1.

Lagena marginato-perforata, Seguenza, 1880, Ibid., p. 332, pl. XVII., fig. 34.

Under the two names given above Seguenza figures two shells which show only trifling differences, and may be brought under the same species. The main difference between the two is that the perforations or pittings in the first are arranged in a regular manner, whilst in the second they are irregularly disposed. In his descriptions Seguenza says nothing of the arrangement of the punctations. In describing *F. punctata* he says that it has a double margin (? keel), but the figure does not show this, only presenting that effect which is always seen in sufficiently transparent shells, and which is caused by the inner and outer boundary lines of the shell-wall as seen in optical section.

The Biarritz specimens are small and very rare.

(Seguenza's names *punctata* and *marginato-perforata* being of the same date, it would be preferable to adhere to the name which has been more generally used, *L. marginato-perforata*, and to abandon *L. punctata*.)

131A. [LAGENA LACUNATA, Burrows & Holland.]

[*Lagena lacunata*, Burrows & Holland in Jones, Parker, and Brady, 1866, etc., MFC. 1895, p. 205, pl. VII, fig. 12.
Lagena orbignyana, var. *lacunata*, Sidebottom, 1912, etc., LSP. 1912, p. 416, pl. XIX. figs. 16-18.]

SUB-FAMILY NODOSARINÆ.

GENUS NODOSARIA, Lamarck.

132. NODOSARIA LÆVIGATA, d'Orbigny.

Nodosaria (*Glandulina*) *lævigata*, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 252, No. 1, pl. X, figs. 1-3.
N. lævigata, Brady, 1884, Chall. Rep., pp. 490 & 493, pl. LXI, figs. 17-22, 32.

Frequent and variable in form according to the degree in which the sutures approach or recede from one another. Another variation is for the sutures to become oblique, thus giving a marginuline appearance to the shell.

132A. [NODOSARIA ÆQUALIS, Reuss.]

[*Glandulina lævigata*, var. *æqualis*, Reuss, 1870, Sitz. d. k. Ak. Wiss. Wien. vol. LII, p. 478;—v. Schlicht, 1870, Foram. Pietzpuhl, pl. VI. figs. 21, 22, 24.
Nodosaria æqualis, Brady, 1884, Chall. Rep., p. 492, pl. XII, fig. 32.]

133. NODOSARIA GLANS, d'Orbigny.

Pl. III, fig. 13

Nodosaria (*Glandulina*) *glans*, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 252, Modèle No. 51.
Nodosaria (*Glandulina*) *glans*, Parker, Jones, & Brady, 1865, Ann. Mag. Nat. Hist., Ser. 3, vol. XVI, No. 91, p. 27, pl. I, fig. 30.

This is a distinctly striate variety of *N. lævigata*. It is stout in form, sometimes almost globular, and almost invariably apiculate at the aboral extremity. Not rare in Gathering No. 6, rare in Nos. 7 and 8.

The striations are fine and regular, extending the whole length of the shell.

I am fully aware that d'Orbigny's species *N. glans* has been assigned by Brady to *N. comata* (Batsch), but I think it advisable to revive the former appellation for those glanduline specimens

which are ornamented with longitudinal striæ, leaving the elongate costate ones as *N. comata.* In fact I consider *N. glans* to be a striate variety of *N. lævigata,* and *N. comata* a costate variety of *N. radicula* (Linné).

(An examination of Halkyard's specimens leads us to agree with his conclusions. Both in shape and external ornament there is a wide difference between this striate variety of *N. lævigata,* d'Orbigny, such as occurs at Biarritz, and the coarsely sulcate form *N. comata* (Batsch) which is a not uncommon recent tropical form.)

134. Nodosaria radicula (Linné.)

Nautilus radicula, Linné, 1758, Syst. Nat., ed. 10, p. 711; 1788, 13th (Gmelin's) ed., vol. I, pt. VI, p. 3373, No. 18.
Nodosaria radicula, Brady, 1884, Chall. Rep., p. 495, pl. LXI, figs. 28-31.

Common in all the Gatherings.

(A very fine series of specimens exhibiting all degrees of rotundity and attenuation, and in some cases displaying a tendency to assume a dentaline curvature of the later chambers.)

135. Nodosaria radicula, var. annulata, Terquem & Berthelin.

Glandulina annulata, Terquem & Berthelin, 1875, Mém. Soc. Géol., France, (2), vol. X, p. 22, pl. I, (XI), figs. 25a, b.
Nodosaria radicula, var. *annulata,* Brady, 1884, Chall. Rep., p. 496, pl. LXII, figs. 1-2.

Not rare, and persisting throughout the whole of the beds. The specimens are more elongated than those figured by Brady, and do not often show the diminishing diameter of the final chambers which gives the typical shell its fusiform contour.

(A few of the specimens show signs of compression, thus assuming a linguline mode of growth, but this may be due to pressure in fossilization.)

136. Nodosaria radicula, var. ambigua, Neugeboren.

Nodosaria ambigua, Neugeboren, 1856, Denkschr. k. Ak. Wiss. Wien, vol. XII, (2), p. 71, pl. I, figs. 13-16.
N. radicula, var. *ambigua,* Brady, 1884, Chall. Rep., p. 496, pl. LXII, fig. 3a, b.

Rare, only 3 small specimens having four segments each were discovered.

136A. [NODOSARIA SIMPLEX, Silvestri.]

[*Nodosaria simplex*, Silvestri, 1872, NFVI, p. 95, pl. XI. figs. 268-272.
N. simplex, Brady, 1884, FC. p. 496, pl. LXII. figs. 4, 5 and ?6.]

137. NODOSARIA (DENTALINA) SILIQUA, Reuss.

Dentalina siliqua, Reuss, 1862 (1863), Sitz. k. Ak. Wiss. Wien, vol. XLVI, (1), p. 40, pl. II, fig. 11.

This variety of *N. radicula* is rather rare, and in these collections is generally somewhat irregular or distorted in growth.

138. NODOSARIA (DENTALINA) PLEBEIA, Reuss.

Dentalina plebeia, Reuss, 1855, Zeitschr. deutsch. geol. Ges., vol. VII, p. 267, pl. VIII, fig. 9.
Nodosaria plebeia, Brady, 1884, Chall. Rep., p. 502, pl. LXIII fig. 2.

A compactly built form which differs only from *N. roemeri*, Neug. in having directly transverse sutures in place of oblique ones. Rare at Biarritz.

139. NODOSARIA (DENTALINA) COMMUNIS, d'Orbigny.

Dentalina communis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 254, No. 35.
Nodosaria communis, Brady, 1884, Chall, Rep., p. 504, pl. LXII, figs. 19-22.

Frequent, varying in form from a delicate many-chambered shell with an acuminate commencement, to a stout shell with few segments and a globular primordial chamber.

(A very fine and extensive series of specimens covering all possible variations of the type.)

140. NODOSARIA (DENTALINA) MUCRONATA, Neugeboren.

Dentalina mucronata, Neugeboren, 1856, Denkschr. k. Ak. Wiss. Wien, vol. XII, (2), p. 83, pl. III, figs, 8-11.
Nodosaria mucronata, Brady, 1884, Chall. Rep., p. 506, pl. LXII, figs. 27-29; monstrous specimens figs. 30, 31.

Rather rare but well distributed. The specimens are generally slender and elongate, and approach *N. communis*.

141. Nodosaria (Dentalina) indifferens, Reuss.

Dentalina indifferens, Reuss, 1863 (4), Sitz. k. Ak. Wiss. Wien, vol. XLVIII, (I), p. 44, pl. II, figs. 15, 16.

This species is of a slender form, having the first segment globular and larger than the succeeding ones. At first the sutures are flush with the surface and not depressed, but afterwards are depressed and the segments oval. The shell has this peculiarity however that the sutures are more deeply excavated on the outer curve of the length than on the inside curve, thus making the chambers more salient on that side. The species is very rare at Biarritz.

(The specimens answer to Reuss's figures, but there seems no logical reason for separating such trifling variations from better known types such as *N. consobrina* d'Orbigny.)

142. Nodosaria (Dentalina) scharbergana, Neugeboren.

Dentalina scharbergana, Neugeboren, 1856, Denkschr. k. Ak. Wiss. Wien, vol. XII, (2), p. 87, pl. IV, figs. 1-4.

Rare and small. Judging from my specimens this is a weak starved form of *N. consobrina*, d'Orb.

(Here again there seems no possible object in perpetuating Neugeboren's specific name. The specimens are *N. consobrina* d'Orbigny.)

143. Nodosaria (Dentalina) filiformis, d'Orbigny.

Nodosaria filiformis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 253, No. 14.
N. (D.) filiformis, Brady, 1884, Chall. Rep., p. 500, pl. LXIII, figs. 3-5.

Rare and found only in the upper half of the Marl. Most of the specimens found are like the form named by d'Orbigny *D. elegans* (1846, Foram. Fossiles Vienne, p. 45; pl. I, figs. 52-56.) *N. filiformis*, Reuss is more nearly allied to *N. farcimen*, (Soldani), having long oval segments with straight sutures.

144. Nodosaria (Dentalina) consobrina, d'Orbigny. Pl. IV, fig. 7.

Dentalina consobrina, d'Orbigny, 1846, Foram. Foss. Vienne, p. 46, pl. II, figs. 1-3.
Nodosaria consobrina, Brady, 1884, Chall. Rep., p. 501, pl. LXII, figs. 23-24.

Common, but never found perfect, the longest fragment consisting of seven segments. Perfectly straight specimens are frequent, thus showing the artificial character of the subgenus *Dentalina*. The forms figured by Brady are by no means typical, but the form figured here almost exactly resembles d'Orbigny's figures.

(A very good series exhibiting great range of variations. Many of the specimens show abnormalities of growth in the diminution and subsequent enlargement of succeeding chambers.)

145. NODOSARIA (DENTALINA) CONSOBRINA, var. EMACIATA, Reuss.

Dentalina emaciata, Reuss, 1851, Zeitschr. deutsch. geol. Ges. vol. III, p. 63, pl. III, fig. 9.
Nodosaria consobrina, var. *emaciata*, Brady, 1884, Chall. Rep., p. 502, pl. LXII, figs. 25-26.

Much less frequent than its type species and apparently confined to the upper half of the Marls. One very fine, thick-walled specimen measuring half-an-inch in length was found in April, 1897. This specimen is armed with a stout spine at the aboral end, and in consequence of the thickness of the wall the sutures are quite flush with the surface of the shell, except in the last two segments where they are very slightly depressed.

(There seems little reason for perpetuating the varietal name in this very variable species. It is moreover singularly inappropriate, as the variety is almost always more strongly marked in its development and growth than the type.)

146. NODOSARIA LONGISCATA, d'Orbigny.

Nodosaria longiscata, d'Orbigny, 1846, Foram. Foss. Vienne, p. 32, pl. I, figs. 10-12.

Common in all gatherings, but owing to its extreme fragility occurs only in fragments.

(Those specimens which exhibit the initial portion of the shell are furnished with a very large and bulbous primordial chamber, as figured by Sherborn and Chapman (S. & C. 1886, etc., M.L.C. 1889, pl. XI, fig. 17.). No specimens with microspheric primordial chambers occur, and the possibility of this species being merely the megalospheric condition of some other at present unidentified must not be lost sight of.)

147. Nodosaria (Dentalina) verneuili, d'Orbigny.

Dentalina verneuili, d'Orbigny, 1846, Foram. Foss. Vienne, p. 48, pl. II, figs. 7, 8.

Rather rare. The specimens have very thick walls, particularly those collected at Gathering 4, in the transverse section of which there can be recognised nine layers of whitish shell-substance alternating with as many rings of darker hue and of less thickness.

(The enormously thick walls built up of concentric layers of shell substance are very noticeable. The identity of this species as apart from *N. pauperata* d'Orbigny appears to us to be somewhat problematical, it is always microspheric whereas *N. pauperata* is always megalospheric. Apart from this distinction the two forms appear to be identical in structure and design.)

148. Nodosaria (Dentalina) farcimen (Soldani.)

Orthoceras farcimen, Soldani, 1791, Testac., vol. I, pt. 2, p. 98, pl. CV, fig. O.
Nodosaria farcimen, Brady, 1884, Chall. Rep., p. 498, woodcuts, 13a, b, c; and pl. LXII, figs. 17, 18.

Very rare, and with segments not quite so much inflated as in the typical form.

149. Nodosaria (Dentalina) rostrata, Seguenza.
Pl. IV, fig. 1.

Dentalina sp., Costa, 1855 (1857), Mem. Acc. Sci. Napoli, vol. II, pl. I, fig. 32.
D. rostrata, Seguenza, 1879-80, Atti. R. Acc. Lincei, (3), vol. VI, p. 221.

This species is rare. Costa figured a specimen from the Tertiary Marl of Messina but did not describe or even name it, which duty was performed twenty-five years later by Seguenza in his work on the Tertiary Formations of the Province of Reggio (Calabria) Italy.

(Except for the produced rostrum to which attention is called by Seguenza, the species does not appear to differ from *N. communis*.)

150. [ELLIPSOIDINA LORIFERA, sp. nov.]

150A. NODOSARIA (DENTALINA) LORIFERA, sp. nov.

Pl. IV, fig. 2, 3.

Test consisting of 8 to 12 oval segments, sutures depressed; aperture, a curved or straight slit situated at the extremity of the final segment and placed transversely in respect to the plane of curvature of the shell. Each segment provided internally with a median band or flat pillar of shell-substance, connecting the margin of each oral aperture with the one preceding it. Length, .85 to 1.45 mm.

This species is frequent in the Biarritz Marls. Externally it resembles somewhat *D. lorneiana*, d'Orb., but when the shell is broken open, or is sufficiently transparent to observe the internal structure, it is seen to possess a very remarkable feature. In viewing the shell mounted in canada balsam by transmitted light the central longitudinal band or strap is very easily visible but may be supposed to be a tube. It is only by carefully breaking up specimens that the true nature of the structure can be really seen. The band (or much flattened pillar) is generally so placed that its broader surface is parallel with the slit-like oral aperture of the shell, close to the internal margin of which it is attached; in rare cases, however, the broad surface may be at right angles to the length of the orifice, in which case it is bifurcated, one of the two divisions or prongs being attached to one side of the aperture, and the other prong to the opposite side, so as to form a bridge over the orifice.

The central pillar is not always straight but often flexuose and is broadest at its point of attachment. The function is not evident as it is much too delicate to be of any use as a support, or means of strengthening the shell, being thinner than the shell-wall in all the specimens I have examined, and moreover not being of good suitable form. If the structure had been columnar or even tubular there might have been some reason to suppose it to fulfil the same purpose as the columns in *Ellipsoidina*, which seem to exist for the purpose of strengthening the test. D'Orbigny figured (Foram. Foss. Vienne, pl. II, figs. 48-51) under the name of *Lingulina rotundata* a *Nodosaria* of the *radicula* type having a slit-like aperture instead of the circular or stellate orifice usual in that genus. Judging from the peculiar form of aperture, which is similar to that of *N. lorifera*, it is quite possible d'Orbigny's species may be also furnished with a similar internal structure, though nothing to that effect is noted in the author's description.

(The internal structure of this very interesting little form shows that it is not a *Nodosaria* but an *Ellipsoidina* and closely allied to *E. subnodosa*, Guppy (G. 1884. F.T. p. 650, pl. XLI, fig. 12). The aperture is also characteristic of that genus. All the Biarritz specimens are regularly tapering and microspheric, whereas in the Trinidad form the initial chamber is but slightly smaller than its successors and the shell is nearly straight instead of curved. It is possible that the two may represent micro- and megalo-spheric forms of the same species but pending further investigation Halkyard's form must stand under the name *Ellipsoidina lorifera*.

The comparison with *Dentalina lorneiana* d'Orbigny does not extend beyond external shape and curvature of the chambers. D'Orbigny's figure exhibits a marked *nodosarian* aperture and there is no suggestion of an internal siphon.

The *Lingulina rotundata* d'Orb., referred to in the text is on the other hand, from its characteristic orifice, evidently an *Ellipsoidina* and probably closely allied to Guppy's form from Trinidad.)

151. Nodosaria (Dentalina) pauperata, d'Orbigny.

Pl. IV, figs. 8, 9, 14, 15.

Dentalina pauperata, d'Orbigny, 1846, Foram. Foss. Vienne, p. 46, pl. I, figs. 57-58.

Nodosaria pauperata, Brady, 1884, Chall. Rep., p. 500, woodcuts 14a, b, c.

This species is common in our collections, and, as might be expected, many deviations from the type can be noted. Figure 9 represents a typical shell, and figure 8 one with elongated segments and approaching in character *Dentalina vetustissima*, d'Orb. In figures 14 and 15 we have two other modifications with globular segments and sharp initial ends to the shells, the latter figure resembles somewhat the form named *Dentalina chrysalis* by Cornuel (Mem. Soc. Géol., France, Sér. 2, vol. III, p. 251, pl. III, fig. 21.) That form, however, has shorter and less deeply excavated sutures. As it may be expedient to distinguish this variety by a name, it would be as well to adopt that given to it by Cornuel, at the same time not retaining the name as of specific importance, but only as a variety of *D. pauperata*. The four varieties just referred to are so intimately connected by innumerable links that it is difficult to separate them, though they appear so different in the drawings. Figs. 10 to 13 are also varieties of *D. pauperata*, d'Orb. but will be described and treated of under other appellations.

(A very extensive series of specimens showing all stages of growth from the typical *N. pauperata* of Orbigny's Vienna Monograph, up to specimens in which the later chambers are separated by a distinct neck.)

152. NODOSARIA (DENTALINA) PAUPERATA, d'Orbigny.

var. BULBOSA, nov.

Pl. IV, figs. 10-11.

Test smooth, consisting of about twelve segments, sutures flush, excepting the last one or two which are slightly depressed. The initial extremity of the shell pointed and increasing in width rapidly, afterwards contracting so that the first five chambers have together a rhomboidal contour which merges into the gradually tapering growth seen in the type. Length 1.4 to 2.35 mm.

This stout form is frequent in the Biarritz Marls, and is always easily recognised as, besides its form, its texture is quite different from the specimens of *D. pauperata* found in the same Gatherings, being apparently more compact.

Costa in his paper on the fossil Foraminifera of the Tertiary Marl of Messina figured a species under the name of *Vaginulina clavata* which seems to be a closely allied form to the one now under discussion. The initial end of Costa's shell, however, is globular and only consists of one chamber.

(The peculiar bulbous form of the initial portion of the shell is very characteristic, but varies to so great an extent that it is hardly reliable even as a varietal distinction. In extreme cases it forms quite a striking feature. The structure of the shell wall appears to be much thicker than in the Biarritz specimens of *N. pauperata*, and identical with the Biarritz *N. verneuili*, with which the variety is perhaps more nearly allied.)

153. NODOSARIA (DENTALINA) PAUPERATA, d'Orbigny.

var. CRASSISEPTA, nov.

Pl. IV, figs. 12, 13.

Test elongate, earlier portion parallel-sided, later portion consisting of globular chambers, sutures limbate. Length, 2.4 to 5.0 mm.

This form, which it has been thought necessary to describe under a new varietal name, is rare. If deprived of its sutural limbation it closely resembles the type and its more closely connected variations; a comparison of figs. 12 and 9, and of fig. 13 with fig. 14 will be sufficient to prove this point.

In 1868 * C. W. Gümbel described and figured a specimen of *Nodosaria* which had limbate sutures; he gave that form the specific name *internodifera*. His figure shows a fragmentary shell consisting of three segments and differing from ours in being quite straight, having long oval segments, and having regular symmetrical limbation on the sutures. It may be noted that the limbation in our variety is asymetrical, or, in other words, the most elevated portion of it is not situated equi-distant from its lateral lines of junction with the surface of the segments.

(Besides the reference to Gümbel's species given above, many other illustrations of *Nodosariæ* with limbate sutures could be supplied. D'Orbigny in 1840 figured, from the Paris Chalk a form allied to *N. farcimen* (Soldani), but with limbate sutures, under the name of *N. limbata*. K. Mittermaier in *Microfauna der Oberen Kreideschichten von Trans-Caucasien* (Erlangen 1896) plate O. fig. 5, figures a fragment described as *Nodosaria sp.* in which the limbation is much greater than in either d'Orbigny's or Halkyard's forms. *Nodosaria cannæformis*, Reuss (R 1860, T.F. p. 364, pl. I, fig. 2) is similarly limbate as the sutures.

To what extent the limbation of these fossils has been increased by the more rapid dissolution of the surface layer of the perforate chambers, as compared with the imperforate shell substance of the sutures, it is impossible to say. Almost certainly some such chemical action has taken place, as we seldom or never find recent specimens of these types showing natural sutural limbation.)

154. Nodosaria (Dentalina) vetustissima, d'Orbigny.

Dentalina vetustissima, d'Orbigny, 1849, Prodome de Paléont, vol. I, p. 242, No. 261.

Frequent. A species nearly allied to *D. pauperata* and connecting that species with *D. consobrina* through the latter's variety *emaciata*.

155. Nodosaria simplex, Silvestri.

Nodosaria simplex, Silvestri, 1872, Atti. Accad. Gioenia Sci. Nat., n.s., vol. VII, p. 95, pl. XI, figs. 268-272.

N. simplex, Brady, 1884, Chall. Rep., p. 496, pl. LXII, figs. 4, 5, and 6?

Specimens small and rare in our Gatherings.

* Abh. math. phys. Cl. k bayer. Ak. Wiss. X. Abth. II. [1868] 1870, p. 611, pl. I, fig. 15.

156. NODOSARIA (DENTALINA) SOLUTA, Reuss.

Pl. IV, fig. 5.

Dentalina soluta, Reuss, 1851, Zeitschr. deutsch, geol., Ges., vol. III, p. 60, pl. III, fig. 4.
Nodosaria soluta, Brady, 1884, Chall. Rep., p. 503, pl. LXII, figs. 13-16; var. pl. LXIV, fig. 28.

Rather rare and fragmentary, principally found in the upper part of the Marl.

157. NODOSARIA (DENTALINA) OLIGOSTEGIA, Reuss.

Pl. IV, fig. 6.

Nodosaria oligostegia, Reuss, 1845-6, Verstein. Böhm. Kreide, vol. 1, p. 27, pl. XIII, figs. 19, 20.
Dentalina oligostegia, Reuss, 1851, Haidinger's Naturw. Abh., vol. IV (1), p. 25, pl. I, fig. 10.

This form is a connecting link between *D. soluta*, Reuss, and *D. consobrina*, d'Orbigny, from both of which species it is easily separable in our Gatherings, for which reasons it is considered advisable to retain it as a separate species, though some recent authors have seen fit to merge it into *D. soluta*. Our figures pl. IV. 5, 6, 7, show clearly its position; they are all drawn to the same scale so that the relative sizes of the three species may be easily seen. Examples are frequent at Biarritz.

(The majority of the specimens might be referred without much hesitation to *N. consobrina*.)

158. NODOSARIA (DENTALINA) GUTTIFERA, d'Orbigny.

Dentalina guttifera, d'Orbigny, 1846, Foram. Foss. Vienne, p. 49, pl. II, figs. 11-13.

Not rare and distributed evenly through the whole of the Marl beds.

159. NODOSARIA PYRULA, d'Orbigny.

Nodosaria pyrula, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 253, No. 13.
N. pyrula, Brady, 1884, Chall. Rep., p. 497, pl. LXII, figs. 10-12.

Rare and weak. The segments are much elongated, as are also the connecting stolons.

160. Nodosaria semirugosa, d'Orbigny.

Nodosaria semirugosa, d'Orbigny, 1846, Foram. Foss. Vienne, p. 34, pl. I, figs. 20-23. (*N. rugosa* on plate.)
N. costulata, Brady, 1884, Chall. Rep., p. 515, p. LXIII, figs. 23-27.

More frequent than the last-named species. Besides the typical form with short costæ on the base of each segment only, there are to be found specimens in which the costæ are longer, and so on by small gradations up to a form in which the surface ornamentation is continuous with the length of the segment. In this case the costæ are sometimes few and feebly developed, and sometimes very strong, in the latter specimens the chambers are more elongate than in the type.

(Halkyard originally named his specimens *N. costulata* Reuss, and would have been well advised to have adhered to this name. The specimens though fragmentary are much nearer the Pietzpuhl figure of *N. stipitata* var. *costulata* Reuss (S. 1870 F.S.P. pl. VII. fig. 20.) with elongate chambers merging imperceptibly into a thick costulate neck, than to d'Orbigny's earlier species *N. semirugosa*, in which the chambers are nearly globular, and the stolon passages long and delicate.)

161. Nodosaria (Dentalina) obliquestriata, Reuss.

Dentalina obliquestriata, Reuss, 1851, Zeitschr. deutsch. geol. Ges. vol. III, p. 63, pl. III, figs. 11, 12.

This species occurs both at the top and bottom of the Marl beds, as well as at some intermediate points, but is rather rare and the specimens are small.

(The specimens are nearly all very small and weak. *N. obliqua* (Linné.) should except for taxonomical purposes include all these costate forms, the variations of the numerous sub-species resting entirely upon the strength of the costæ and their tendency to follow the curve of the shell, or to run transversely across the chambers.)

162. Nodosaria perversa, Schwager.

Nodosaria perversa, Schwager, 1866, Novara-Exped., Geol. (2), p. 212, pl. V, fig. 29.
N. perversa, Brady, 1884, Chall. Rep., p. 512, pl. LXIV, figs. 25-27.

Small and rare, out of the eight examples found seven were in material from No. 8 Station, which is one of the lowest in the Marl.

(The specimens though small and distorted by compression are fairly typical.)

163. NODOSARIA (DENTALINA) OBLIQUATA (Batsch).

Nautilus (Orthoceras) obliquatus, Batsch, 1791, Conch. Seesandes, pl. II, figs. 5a, d.

Nodosaria obliquata, Fornasini, 1890, Boll. Soc. Geol. Ital. vol. IX, fasc. 1, pl. VIII, figs. 1-7.

Rather rare. Fornasini says, "*N. obliquata* is dimorphic, that is to say, presents itself under the two forms which it is agreed to call 'A and B.'" The large majority of the Biarritz specimens are of the megalospheric or "Form A" type.

(See note to 161.)

164. NODOSARIA (DENTALINA) MULTICOSTATA, d'Orbigny.

Dentalina multicostata, d'Orbigny, 1840, Mém. Soc. Géol., France, [1], vol. IV, p. 15, pl. I, figs. 14-15.

D. multicostata, Brady, 1876, Carbonif. Foram., Palæont. Soc., vol. XXX, p. 129, pl. X, fig. 19.

Very rare. Only two or three fine characteristic specimens were found, which are more slender in form than the original figure given by d'Orbigny.

One specimen worthy of note was found in the Gatherings of April, 1897. This example consists of five segments, the first one being larger than the second and furnished with a short spine at the aboral extremity. The test only shows a slight tendency to become dentaline. It is evident that we have here the megalospheric form of this species.

(Of the few specimens the majority are very characteristic and closely resemble d'Orbigny's figure.)

165. NODOSARIA (DENTALINA) VERTEBRALIS, (Batsch.)

Nautilus (Orthoceras) vertebralis, Batsch, 1791, Conch. Seesandes, pl. II, figs. 6a, b.

Nodosaria vertebralis, Brady, 1884, Chall. Rep., p. 514, pl. LXIII, fig. 35, and pl. LXIV, figs. 11-14.

Frequent. Found in all the Gatherings except No. 9 (1893).

166. Nodosaria raphanus (Linné).

Nautilus raphanus, Linné, 1758, Syst. Nat. ed. 10, p. 711.
Nodosaria raphanus, Brady, 1884, Chall. Rep., p. 512, pl. LXIV, figs. 6-10.

Not rare. The specimens are long and slender with well-marked costæ, which are not always parallel with the axis of the shell but occasionally obliquely disposed. This feature, together with the fact that there is also sometimes a slight curvature of the shell, shows a distinct relationship with *Dentalina obliquata* (Batsch). In the latter species, however, the costæ are not prominent or trenchant.

167. Nodosaria (Dentalina) acute-costata, Silvestri.

Nodosaria acute-costata, Silvestri, 1872, Atti Accad. Gioenia. Sci. Nat., s. 3, vol. VII, p. 48, pl. IV, figs. 82-89.

This variety of *N. raphanus* has the commencement of the shell pointed and sometimes hooked, that is to say, it begins with rather a sharp curvature which becomes flatter as additional segments are added, and may become perfectly straight. The costæ are few and strong, and generally oblique on the earlier portion of the test.

(The species cannot be usefully separated from *N. raphanus*.)

168. Nodosaria raphanistrum (Linné).

Pl. IV, fig. 4.

Nautilus raphanistrum, Linné, 1758, Syst. Nat., ed. 10, p. 710; 1788, ed. 13 (Gmelin's), p. 3,372.
Nodosaria raphanistrum, Jones, Parker, and Brady, 1866, Crag. Foram., Palæont. Soc., vol. XIX, p. 50, pl. I, figs. 6-8.

This species is frequent in the Marls of Biarritz, but owing to their length the specimens are not often found unbroken. The forms known as *Nodosaria affinis*, d'Orb., and *N. bacillum*, Defr. are both found; the latter attaining the greatest dimensions, two examples each measure nearly $\frac{3}{4}$in. in length, whilst the other form only reach half that length.

I have thought fit to give a figure of a transverse section of a specimen in order to show the constitution of the shell wall. It will be seen that the costæ are wedge-shaped in section and are composed of compact imperforate substance, and that the shell-wall proper, between the costæ, is composed of several

layers of matter. Though the figure shows this much, it is necessary to add that the shell-substance between the costæ is perforate. The laminated appearance proves that the thickening of the wall and deposition of calcareous matter is not a continuous process, but that there are periods of deposition alternating with resting periods, as in the formation of the woody layers of a tree trunk.

169. NODOSARIA SCALARIS (Batsch).

Nautilus (*Orthoceras*) *scalaris*, Batsch, 1791. Conch. Seesandes pl. II, 4a, b.

Nodosaria scalaris, Brady, 1884, Chall. Rep., vol. IX, p. 510, pl. LXIII, figs. 28-31, and LXIV, figs. 16-19.

This species is extremely rare in these Marls. One specimen consisting of four chambers was found in material collected in 1902 from sandy veins and pockets in the soft beds exposed between tides at the end of the Quai des Basques.

170. NODOSARIA COMATA (Batsch).

Nautilus (*Orthoceras*) *comatus*, Batsch, 1791. Conch. Seesandes, pl. I, fig. 2a, b.

Nodosaria comata, Brady, 1884, Chall. Rep., vol. IX, p. 509, pl. LXIV, figs. 1-5.

This may be said to be a costate variety of *N. radicula*, or a form closely allied to *N. scalaris*, differing from the last in being of a more robust habit, having the sutures less excavated, not possessing a produced neck at the oral extremity, and lacking the elegance of form displayed by well-grown specimens of *N. scalaris*. It differs from *N. radicula* in being ornamented with longitudinal costæ and, instead of being cylindrical as that species is, *N. comata* almost invariably has the chambers increasing in diameter from the first to the last.

It is also very rare at Biarritz, only one specimen is noted which was obtained from a small quantity of marl collected at the top of the cliff about 200 yards south of the villa known as l'Ermitage.

171. NODOSARIA OLIGOTOMA, Reuss.

Nodosaria obligotoma, Reuss, 1872. Geinitz Palæont, vol. XX (1), p. 135, pl. XXXIII, fig. 16.

A delicate fusiform shell with both ends sharply pointed. It generally consists of four or five segments and is ornamented

with a few longitudinal costæ. Only three specimens were found in the whole of the material examined and these were small and weak.

(A weak variety of *N. raphanus* (Linné).)

172. Nodosaria (Dentalina) adolphina, d'Orbigny.

Pl. 4, fig. 16.

Dentalina adolphina, d'Orbigny, 1846. Foram. Foss. Vienne, p. 51, pl. II, figs. 18-20.
D. adolphina, Sherborn and Chapman, 1886, Journ. Roy. Micr. Soc. [2], vol. VI, p. 750, pl. XV, fig. 11a, b.

Common in these Marls. As usual when a great number of specimens are examined much variation is found to exist both in the form of the shells and the nature of the surface ornamentation. In our gatherings the form varies from a slender many-chambered shell with no sutural depressions in the earlier portion, to a stouter shell with comparatively few globular segments with well-marked sutures. The former variety has the whole of the later segments covered with prickles, and the latter is smooth as shown in the drawing on pl. IV. Between these two extreme varieties there are to be found innumerable gradations both in form and surface-ornamentation.

(Of the two forms referred to by Halkyard, the tuberculate is the true *N. adolphina*, as figured and described by d'Orbigny. The smooth variety appears to occupy a position intermediate between *N. adolphina* and *N. pauperata*, and some of the stouter specimens are indistinguishable from the weaker examples of *N. pauperata* in the Halkyard collection.)

173. [Nodosaria spinosa (d'Orbigny.)]

173a. Nodosaria (Dentalina) spinulosa (Montagu).

Nautilus spinulosus, Montagu, 1808, Testac. Brit. Suppl. p. 86, pl. XIX, fig. 5.
Dentalina spinulosa, Sherborn and Chapman, 1886, Journ. Roy. Micro. Soc., [2] vol. VI, p. 751, pl. XV, fig. 13.

Frequent, but the specimens are not typical. The earlier chambers of the shells are invariably ornamented with longitudinal costæ, which later are interrupted or broken up into short lengths, and, later still, into spines or prickles pointing backwards. The prickles first make their appearance on the basal portion of each segment.

(All the specimens should in our opinion be referred to *N. spinosa* (d'Orbigny) (d'O. 1846 F.F.V. p. 56. pl. II. figs. 36, 37.) They none of them present the characteristics of Montagu's form.)

174. NODOSARIA (DENTALINA) ACUTA, d'Orbigny.

Dentalina acuta, d'Orbigny, 1846, Foram. Foss. Vienne, p. 56, pl. II, figs. 40-43.

A slender sharp-pointed ally of *Nodosaria raphanus* (Linné) with a few well-marked longitudinal costæ. It is not rare in our gatherings.

(This appears to be a slender dentaline form of *N. raphanus*, intermediate between that species and *N. vertebralis* (Batsch.).

175. NODOSARIA HISPIDA, d'Orbigny.

Nodosaria hispida, d'Orbigny, 1846, Foram. Foss. Vienne, p. 35, pl. I, figs. 24-25.
N. hispida, Brady, 1884, Chall. Rep., p. 507, pl. LXIII, figs. 12-16.

Rather rare but evenly distributed.

(Many of the specimens might equally well be assigned to a variety of *N. adolphina*, with aculeate processes extending over the whole of the chambers.)

176. NODOSARIA ASPERA, Silvestri.

Nodosaria aspera, Silvestri, 1872, Atti Accad. Gioenia, Sci. Nat., n.s., vol. VII, p. 76, pl. VIII, figs. 191-200.

Rarer than the last named species and differing from it in having the surface ornamented with minute tubercles instead of small closely-set spines. It is a question whether it would not be best to merge the two species into one under d'Orbigny's specific appellation, that having the priority in point of date over Silvestri's.

GENUS LINGULINA, d'Orbigny.

177. LINGULINA CARINATA, d'Orbigny.

Lingulina carinata, d'Orbigny, 1826, Ann. Sci. Nat. vol. VII, p. 257, No. 1.
L. carinata, Brady, 1884, Chall. Rep., p. 517, pl. LXV, figs. 16-17.

Rare. Found principally in the middle layers of the Marl.

Genus Lingulinopsis, Reuss.

178. Lingulinopsis acutimargo, sp. nov.

Pl. V, fig. 1.

Two specimens were found which differ from *Lingulina* in that the early portion of the shell is formed on the spiral plan of growth as in *Cristellaria*, and later becomes linear as in *Lingulina*. Apart from this dual plan of arrangement of the chambers there is nothing to distinguish my specimens from the typical *Lingulina carinata*, d'Orb., and, but for the fact of more than one example being found of this type, I might have felt inclined to include it with the preceding species, though an abnormal individual of it. Under the circumstances it is advisable however to refer the Biarritz specimens to Reuss' genus which was founded for the inclusion of species having a similar plan of growth. The dimensions of a well-grown specimen are:—Length, .72 mm. Breadth, .63 mm.

(In our opinion *Lingulinopsis* is a genus of no morphological importance. These specimens should therefore be referred to *Lingulina carinata*. The presence of a minute spiral initial portion is of fairly frequent occurrence in *Lingulina* though it seldom reaches the same development as the flabelline spiral of *Frondicularia*.)

Genus Vaginulina, d'Orbigny.

179. Vaginulina legumen (Linné.)

Nautilus legumen, Linné, 1758, Syst. Nat., ed. 10, p. 711; 1788, 13th ed. (Gmelin's), p. 3,373.

Vaginulina legumen, Brady, 1884, Chall. Rep., p. 530, pl. LXVI, figs. 13-15.

This species is rare at Biarritz, but all the same specimens show considerable variation, ranging from a delicate compressed form with an aboral spine to a stout form with a globular primordial segment and circular section, and which only proclaims its affinity to the genus by the extreme excentricity of its oral aperture.

(Some of the delicate compressed forms in the Halkyard collection are very near the specimens which we figured from the West of Scotland (H-A. & E. 1916. F.W.S. p. 256. pl. XLII. figs. 1, 2,) as vaginuline forms of *Nodosaria communis* d'Orbigny.)

180. VAGINULINA RECTA, Reuss, var. PARALLELA, nov.
Pl. V, figs. 5-6.

This is a new variety, the characteristics of which are sufficiently well shown in the drawings here given. It may be that the elevated margins of the segments are too much accentuated in the figures, but this is an error on the right side and leaves no doubt as to this feature of the variety. It will be seen that the lateral surfaces of the segments are flat, even in the case of the primordial one, which in the type species is globular. The squareness and small number of the segments ought also to be noticed. The variety is very rare at Biarritz. The length of the largest specimen found is .9mm., so it will be seen that this variety is smaller than its type species.

(The mere absence of an inflated primordial chamber seems quite insufficient for the creation of a new variety. With this exception the specimens agree very well with Reuss's species, a typical Gault fossil.)

GENUS RHABDOGONIUM, Reuss.

181. RHABDOGONIUM TRICARINATUM (d'Orbigny.)

Vaginulina tricarinata, d'Orbigny, 1826, Ann. Sci. Nat. vol. VII, p. 258, No. 4.
Rhabdogonium tricarinatum, Brady, 1884, Chall. Rep., p. 525, pl. LXVII, figs. 1-3.

Specimens are small but not rare.

GENUS MARGINULINA, d'Orbigny.

182. MARGINULINA GLABRA, d'Orbigny.

Marginulina glabra, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 259, No. 6.
M. glabra, Brady, 1884, Chall. Rep., p. 527, pl. LXV, figs. 5-6.

Frequent, and varying from short stout forms with three or four segments to more slender specimens having about six chambers.

183. MARGINULINA CEPHALOTES (Reuss.)

Cristellaria cephalotes, Reuss, 1862 (1863), Sitz. k. Ak. Wiss. Wien, vol. XLVI, (1), p. 67, pl. VII, figs. 5, 6.

Very rare. In my opinion it is advisable to refer this species to the genus *Marginulina*, chiefly on account of its

intimate relationship with *M. glabra*, d'Orb., which affinity is clearly seen in the Biarritz specimens. At the best it is but an aberrant member of the genus *Cristellaria*, as its transverse section is always circular and not compressed, and it is never truly spiral at the commencement. These two points taken together are important.

(We should have no hesitation whatever in referring these specimens to *Marginulina glabra*.)

184. Marginulina inæqualis, Reuss.

Marginulina inæqualis, Reuss, 1860. Sitz. k. Ak. Wiss. Wien, vol. XL, p. 207, pl. VII, fig. 3.
M. inæqualis, Chapman, 1894, Journ. Roy. Micr. Soc., p. 160, pl. IV, fig. 12.

Specimens are rare in my Gatherings and vary considerably in form.

185. Marginulina parkeri, Reuss.

Marginulina parkeri, Reuss, 1862 (1863), (1), Sitz. k. Ak. Wiss. Wien, vol. XLVI, p. 59, pl. V, fig. 14a, b.
M. parkeri, Chapman, 1898, Journ. Roy. Micr. Soc., p. 13, pl. II, fig. 8.

This species is rarely found in the Biarritz Marls but is so typical that it is not easily confounded with other species occurring in the same Gatherings.

186. Marginulina tumida, Reuss.

Marginulina tumida, Reuss, 1851. Zeitschr, deutsch. geol. Ges., vol. III, p. 64, pl. III, fig. 14.

Rather rare. Forms a connecting link between the last named species and *M. linearis*, Reuss.

187. Marginulina linearis, Reuss.

Marginulina linearis, Reuss, 1862 (1863). Sitz. k. Ak. Wiss. Wien. vol. XLVI, (1), p. 60, pl. V, fig. 15a, b.
M. linearis, Chapman, 1894, Journ. Roy. Micr. Soc., p. 161, pl. IV, fig. 14.

Rare and found chiefly in the upper portion of the Marl.

188. MARGINULINA APICULATA, Reuss.

Marginulina apiculata, Reuss, 1851. Haidinger's Naturw. Abh., vol. IV, (1), p. 28, pl. I, fig. 18.

Extremely rare. Only one small specimen found.

189. MARGINULINA HAMULUS, Chapman.

Marginulina hamulus, Chapman, 1893 (1894), Journ. Roy. Micr. Soc., p. 161, pl. IV, fig. 13a,

Very rare, two specimens found. One in Gathering No. 1, the other in No. 8.

190. MARGINULINA COSTATA (Batsch.)

Nautilus (*Orthoceras*) *costatus*, Batsch, 1791, Conch. Seesandes, pl. I, fig. 1a, g.

Marginulina costata, Brady, 1884, Chall. Rep., p. 528, pl. LXV, figs. 10-13.

This costate variety of *M. glabra* is very rare at Biarritz and the specimens are small.

191. MARGINULINA OBLIQUESTRIATA, Karrer.

Marginulina obliquestriata, Karrer, 1861 (1862), Sitz., k. Ak. Wiss. Wien, vol. XLIV, (1), p. 446, pl. I, fig. 8.

Not so rare as the last species and the examples are larger.

192. MARGINULINA HIRSUTA, d'Orbigny.

Marginulina hirsuta, d'Orbigny, 1826. Ann. Sci. Nat., vol. VII, p. 259, No. 5.

Frequent in Gathering No. 4, less so in No. 7. The specimens are small and have numerous segments.

(D'Orbigny's figure of *M. hirsuta* (d'O. 1846. F.F.V. p. 69, pl. III, figs. 17, 18.) shows a strongly hispid shell with minute marginuline initial portion followed by a series of globular chambers. The Biarritz specimens though slightly curved have no initial spiral, and are much nearer to d'Orbigny's figure of *Dentalina floscula* (d'O. 1846 F.F.V. p. 50. pl. II, figs. 16, 17.) though slightly longer and with more numerous chambers. *D. floscula* is, as d'Orbigny has pointed out, closely allied to *N. hispida* from which it differs only in its curvature. Halkyard's specimens should we think be assigned to *N. hispida* d'Orbigny.)

193. MARGINULINA PYRAMIDALE, (Karrer), var. GLOBOSA, nov.

Pl. V, fig. 2.

This species was figured and described by Karrer in 1861* and was placed in the genus *Rhabdogonium*, probably on account of its triangular transverse section. On reference to his drawings it is seen that the shell has a certain curvature in the longitudinal axis, and moreover the oval aperture is excentrically placed, so that the shell would be in a truer position if transferred to *Marginulina*. The new variety which is very rare, now figured and described, bears out this view. It differs from the type species chiefly in having more globular chambers and the sutures more deeply excavated. Length, 6 mm.

I have obtained from the Blue Marl, near Antibes, South France, some fine specimens of *M. pyramidale* (Karrer); these examples display still more clearly their true genus than the Biarritz shells. They may be briefly described as long, slender, and tapering, having a small globular primordial chamber armed with a long spine at the base, the sutures are oblique on the two lateral faces, and the oral orifice is placed at the dorsal angle of the final chamber.

(Halkyard's specimens are markedly megalospheric whilst Karrer's figure represents a microspheric form. The two forms are probably therefore identical.)

194. MARGINULINA BEHMI (Reuss.)

Pl. V. figs. 3, 4.

Cristellaria behmi, Reuss, 1865. Denkschr. k. Ak. Wiss. Wien, vol. XXV, p. 138, pl. II, fig. 37.

Marginulina behmi, Jones, 1876, M. Micr. Journ., vol. XV, pl. CXXIX, fig. 3.

The figures given on Pl. V represent the megalospheric and the microspheric forms of this species. The latter is the rarer of the two forms, and I am not aware that it has been previously recorded. If the microspheric form (fig. 4) had been discovered alone , without its companion, it would undoubtedly have been referred to Schlumberger's genus *Amphicoryne* which has the earlier chambers cristellarian followed by a nodosarian series. The presence and identification of these two forms of the same species leaves no doubt in my mind as to the ultimate abandonment of the genus *Amphicoryne* and it now remains to search for the companion of *A. falx* (J.& P.) which is the most characteristic species of that genus.

* *Rhabdogonium pyramidale*, Karrer, 1861, Sitz. d.k. Ak. Wiss. Wien. vol. XLIV. (1862), Abth. I, p. 444. pl. 1. fig. 5.

The species is fairly common at Biarritz.

(The very extensive and interesting series of both megalospheric and microspheric specimens lends considerable value to Halkyard's remarks as to the true nature of Schlumberger's subgenus *Amphicoryne*, although it is not very evident what the megalospheric form of *A. falx* can be, assuming his theory to be correct that that species is the microspheric form of some hitherto unconnected species of *Marginulina*. The only form with which *A. falx* has any apparent connexion, is *Nodosaria scalaris* (Batsch) but although we not infrequently find *N. scalaris* with *Amphicoryne* initial portions, they are apparently merely "sports," that is to say microspheric *N. scalaris* with a tendency to axial curvature.

The megalospheric and microspheric forms of *Marginulina behmi* are abundant in the Miocene of Malta, and attain even better development than in the Biarritz gatherings.)

195. MARGINULINA TRIANGULARIS, d'Orbigny.

Marginulina triangularis, d'Orbigny, 1846. Foram. Foss. Vienne, p. 71, pl. III, figs. 22-23.

Rather rare and small. This is a species which can be claimed by either of the genera *Cristellaria* and *Marginulina*.

(Halkyard's specimens agree fairly well with d'Orbigny's figures, but there seems very little reason for separating them from any other of the very various forms of *Cristellaria crepidula* (F. & M.).)

GENUS FRONDICULARIA, Defrance.

196. FRONDICULARIA COMPLANATA, Defrance.

Frondicularia complanata, Defrance, 1824. Dict. Sci. Nat. vol. XXXII, p. 178, Atlas. Conch. pl. XIV, fig. 4.

Very rare. Only two imperfect specimens of the elongate form found in the whole of the material examined.

(Of the two specimens one is flabelline in the initial portion.)

196a. [FRONDICULARIA SPATHULATA, Brady.]

[*Frondicularia spathulata*, Brady, 1879, etc., RRC. 1879, p. 270, pl. VIII. fig. 5.
Frondicularia spathulata, Brady, 1884, FC. p. 519, pl. LXV. fig. 18.]

197. Frondicularia alata, d'Orbigny.

Frondicularia alata, d'Orbigny, 1826. Ann. Sci. Nat. vol. VII, p. 256, No. 2.

F. alata, Brady, 1884, Chall. Rep., p. 522, pl. LXV, figs. 20-23; and pl. LXVI, figs. 3-5.

Extremely rare. A single specimen obtained from Gathering No. 1, (1893).

198. Frondicularia goldfussi, Reuss.

Frondicularia goldfussi, Reuss, 1860, Sitz. k. Ak. Wiss Wien, vol. XL, p. 192, pl. IV, fig. 7.

This is a delicate lanceolate form of *F. alata*. The test is very thin and produced at the base into a long spine. The Biarritz specimens, which are not rare, are almost invariably of flabelline growth and the primordial segment is long and narrow, instead of being globular as is usual in the nodosarian type.

199. Frondicularia ferruginea (Terquem.)
Pl. V. fig. 7.

Flabellina ferruginea, Terquem, 1876. Bull. Soc. Géol. France. [3]. vol. IV, p. 491, pl. XVI, figs. 18-19.

Very rare in the Marl. This species was described by Terquem as occurring in the Bajocian Beds of the Moselle district. The specimens figured by him are of the flabelline form, whilst the few found by me in the Biarritz Marl are of the true frondicularian type. The species is of the *complanata* type, but differs from it in having the sutures depressed and the lateral surfaces of the segments salient. It also may have a slight keel on the margin of the earlier segments.

200. Frondicularia inæqualis, Costa.

Frondicularia inæqualis, Costa, 1855 (1857), Mem. Acc. Sci. Napoli, vol. II, p. 372, pl. III, fig. 3.

F. inæqualis, Brady, 1884, Chall. Rep., p. 521, pl. LXVI, figs. 8-12.

Rather rare. Found only in Gatherings No. 5 and 9, 1893.

201. Frondicularia archiaciana, d'Orbigny.

Frondicularia archiaciana, d'Orbigny, 1840, Mém. Soc. Géol. France [1], vol. IV, p. 20, pl. I, figs. 34-36.

F. archiaciana, Brady, 1844, Chall. Rep., p. 520, pl. CXIV, fig. 12.

Very rare and fragmentary.

202. FRONDICULARIA INTERRUPTA, Karrer.

Frondicularia interrupta, Karrer, 1877, Abh. k. k. geol. Reichsanst, vol. IX, p. 380, pl. XVI, b, fig. 27.
F. interrupta, Brady, 1884, Chall. Rep., p. 523, pl. LXVI, figs. 6-7.

Rare, and found principally at the top of the Marl Beds.

(Costa in 1855, (C. 1855 (1857) F.F.M.M. p. 373, pl. II. fig. 25,) had already used the name *Frondicularia interrupta* for a fossil form but, as the specimen figured by him is a *Vaginulina*, the specific name *interrupta* remains available for Karrer's species, a true *Frondicularia*.)

203. FRONDICULARIA ARBORESCENS, sp. nov.

Pl. V, figs. 8-9.

Test leaf-shaped, flat, compressed, broadest about the middle, generally provided with a marginal keel. Ornamentation on earlier segments raised, reticulated, later giving way to arborescent raised lines branching from the fine limbations which mark the sutures. Length, 1.45 mm. Breadth, 1.3 mm.

This new species is very rare. It is of the *complanata* type, and its appearance is so peculiar that it is very easily recognised. Fig. 8 on pl. V represents the largest and most perfect specimen found, and fig. 9 a fragment which shows in a marked degree the strong reticulation of the first-formed portion of the test. Only the flabelline form has been found so far.

(Halkyard's species is evidently nearly akin to *Flabellina reticulata* Reuss (R. 1851. F.K.L. p. 30. pl. I. fig. 22.) from which it differs in its greater breadth, its acute or carinate margin and the comparatively irregular arrangement of the reticulations between the costate edges of the chambers. Decoration of any kind is a rare feature among the *Frondiculariæ*. A note among the Halkyard MSS. indicates that he had considered the species of Reuss, but regarded it as too irregular in formation and ornament to cover his specimens.)

GENUS CRISTELLARIA, Lamarck.

204. CRISTELLARIA COMPRESSA, d'Orbigny.

Cristellaria compressa, d'Orbigny, 1846, Foram. Foss. Vienne, p. 86, pl. III, figs. 32-33.
C. compressa, Brady, 1884, Chall. Rep., p. 538, pl. CXIV, figs. 15-16.

Very rare. Two small specimens consisting of five and seven segments respectively were found in Gatherings 5 and 6, 1893.

(The specimens are small, and by no means well developed even as compared with the original figure of d'Orbigny. The Challenger figures (Chall. Rep. p. 538. pl. CXIV, fig. 15, 16.) though probably referable on general structure to d'Orbigny's species are very much thinner and have more numerous chambers. They probably represent growth under more favourable conditions of depth.)

205. Cristellaria tenuis (Bornemann.)

Marginulina tenuis, Born. 1855, Zeitschr, deutsch. geol. Ges., vol. VII, p. 326, pl. XIII, fig. 14.
Cristellaria tenuis, Brady, 1884, Chall. Rep., p. 535, pl. LXVI, figs. 21-23.

This species is very rare in the Biarritz Marl. Only two small specimens being taken from Gathering No. 3 (1893.)

206. Cristellaria schlönbachi, Keuss.

Cristellaria schlönbachi, Reuss, 1862 (3). Sitz. k. Ak. Wiss. Wien, vol. XLVI, (1), p. 65, pl. VI, figs. 14-15.
C. schlœnbachi, Brady, 1884, Chall. Rep., p. 539, pl. LXVII, fig. 7.

Rare in all our Gatherings.

207. Cristellaria crepidula (Fichtel & Moll.)

Nautilus crepidula, Fichtel & Moll, 1798, Test. Micr. p. 107, pl. XIX, figs. g-i.
Cristellaria crepidula, Brady, 1884, Chall. Rep. p. 542, pl. LXVII, figs. 17, 19, 20; and pl. LXVIII, figs. 1-2.

Very rare. One fine specimen found in material collected April, 1897, and two small ones in April, 1893.

208. Cristellaria recta, d'Orbigny.

Cristellaria recta, d'Orbigny, 1840, Mém. Soc. Géol. France, [1], vol. IV, p. 28, pl. II, figs. 23-25.

This species which leads from *C. crepidula* to *C. italica* through *C. acutauricularis* and *C. triangularis* is rare, but persistent throughout the Marls. It is represented by single

specimens or at most two examples in nearly all the Gatherings taken.

(The species, like many other of those separated by Halkyard, is hardly worth recordng as apart from its nearest ally *C. crepidula*.)

209. CRISTELLARIA LITUOLA, Reuss.

Cristellaria lituola, Reuss, 1845-6, Verstein. Böhm. Kreide, vol. II, p. 109, pl. XXIV, fig. 47.
C. lituola, Chapman, 1894, Journ. Roy. Micr. Soc., p. 650, pl. IX, fig. 14a, b.

More frequent than the last species but still rare. The species is closely connected with *C. gibba*, d'Orb, but is more compressed and also the unrolling of the spire is carried out to a greater extent.

(The specimens agree on the whole very well with Reuss's original figure. It may be regarded as a transition form between *C. crepidula* and *C. gibba*.)

210. CRISTELLARIA ROBUSTA, sp. nov.

Pl. VI, fig. 1.

Test elongate. Segments arranged spirally at first, afterwards in a cylindrical linear series. Aperture situate at the dorsal extremity of the last segment. Length of well grown specimens, 1.7 mm.

This is one of the numerous forms which connect *Marginulina* with *Cristellaria*. The linear series of chambers is circular in section and the aperture is eccentrically placed. So far the species is marginuline. The earlier portion of the shell forms a complete spiral, in fact, it is a small *C. rotulata* (Lamarck) even to the elevation of the central boss. Its nearest ally in *Marginulina* is *M. ensis*, Reuss, which species it closely resembles in the form and segmental arrangement of the linear portion of the test.

This species can hardly be called rare in the Biarritz Marls but is found, generally speaking, to be confined to the upper half of the beds.

(There seems very little justification for adding this species to the already vast number of Cristellarians. But for the general rotundity of its cross section, *Vaginulina legumen* (Linné) covers practically the features on which Halkyard lays

stress. A more specialized form exhibiting rotundity is *Cristellaria saulcyi* d'Orbigny (d'O. 1839. F.I.C. p. 126. pl. III. figs. 7-9). D'Orbigny's figure agrees with Halkyard's types except for the smaller number of chambers in the produced series. Goës (G. 1894, A.S.F. p. 63, pl. XI, figs. 625, 626,) illustrates under d'Orbigny's specific name elongate specimens comparable in every respect with Halkyard's fossils.)

211. Cristellaria bononiensis, Berthelin.

Cristellaria bononiensis, Berthelin, 1880, Mém. Soc. Géol. France, [3], vol. 1, p. 55 pl. III, (XXVI), fig. 23a-c.
C. bononiensis, Chapman, 1894, Journ. Roy. Micr. Soc. p. 652, pl. X, fig. 9a, b.

Extremely rare. Only one small specimen found in the whole of the Gatherings.

(The single specimen is not very satisfactory as compared with Berthelin's figure, being too compressed and vaginuline. It might equally well have been allotted to an elongate type of *C. tricarinella*, Reuss.)

212. Cristellaria acutauricularis, (Fichtel & Moll.)

Nautilus acutauricularis, Fichtel & Moll, 1798, Test. Micr., p. 102, pl. XVIII, figs. g-i.
Cristellaria acutauricularis, Brady, 1884, Chall. Rep., p. 543, pl. CXIV, fig. 17a, b.

Rare and small.

213. Cristellaria triangularis, d'Orbigny.

Cristellaria triangularis, d'Orb., 1840, Mém. Soc. Géol., France, [1], vol. IV, p. 27, pl. II, figs. 21-22.
C. triangularis, Chapman, 1894, Journ. Roy. Micr. Soc., p. 651, pl. X, fig. 3a, b.

Very rare. Can hardly be distinguished from *C. italica*, (Defr.) It is convenient to separate the stout, broad forms, with rounded angles from the more acutely angled and neater built shells, which latter may be grouped under *C. italica*. No line of demarcation can be drawn between the two varieties, one merging into the other.

(This is merely a passage form between *C. acutauricularis* and *C. italica*, hardly worth separating from the latter.)

214. CRISTELLARIA ITALICA, (Defrance.)

Saracenaria italica, Defrance, 1824. Dict. Sci. Nat. XXXII, p. 177, vol. XLVII, p. 344, Atlas Conch. pl. XIII, fig. 6.
Cristellaria italica, Brady, 1884, Chall. Rep., p. 544, pl. LXVIII, figs. 17, 18, 20-23.

Frequent and found in all Gatherings. The specimens do not usually attain large dimensions.

215. CRISTELLARIA LATIFRONS, Brady.

Cristellaria latifrons, Brady, 1884, Chall. Rep., vol. IX, p. 544, pl. LXVIII, fig. 19; and pl. CXIII, fig. 11a, b.
C. latifrons, Chapman, 1894, Journ. Roy. Mic. Soc., p. 652, pl. X, fig. 8a, b.

Very rare, single specimens found in Gatherings No. 1 and 2 (1893). These small examples resemble Brady's drawing on plate LXVIII, of the "Challenger" monograph, rather than that of plate CXIII., in that the angles of the shell are acute but not carinate. The tests are also more elongate than in Brady's last figure.

(The specimens are far from satisfactory, as the edges do not possess the sharp subcarinate margin which is typical of Brady's species. We should have been inclined to refer them to *C. crepidula*.]

216. CRISTELLARIA GIBBA, d'Orbigny.

Cristellaria gibba, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 292, No. 17.
C. gibba, Brady, 1884, Chall. Rep. vol. IX, p. 546, pl. LXIX, figs. 8-9.

Extremely rare. A single typical example found in Gathering 6 (1893.)

217. CRISTELLARIA CRASSA, d'Orbigny.

Cristellaria crassa, d'Orbigny, 1846, Foram. Foss. Vienne, p. 90, pl. IV, figs. 1-3.
C. crassa, Brady, 1884, Chall. Rep., vol. IX, p. 549, pl. LXX, fig. 1a, b.

Rather rare and sparsely distributed, occurring both at the top and bottom of the Marl and also in several intermediate Gatherings. The specimens are typical and robust.

218. CRISTELLARIA ROTULATA, (Lamarck.)

Lenticulites rotulata, Lamarck, 1804, Ann. Mus., vol. V. p. 188, No. 3; and T. Encyc. Méthod., pl. CCCCLXVI, fig. 5.
Cristellaria rotulata, Brady, 1884, Chall. Rep., vol. IX, p. 547, pl. LXIX, fig. 13a, b.

This species is common throughout the Marl and sometimes attains a large size. One specimen has been found which measures 3/16ths of an inch on its largest diameter.

219. CRISTELLARIA ROTULATA var. MACRODISCUS, Reuss.

Cristellaria macrodiscus, Reuss, 1862 (1863), Sitz. k. Ak. Wiss. Wien, vol. XLVI, (1), p. 78, pl. IX, fig. 5.
C. rotulata, var. *macrodiscus*, Chapman, 1896, Journ. Roy. Micr. Soc., p. 6, pl. I, fig. 9a, b.

This variety is not so frequent as the type and it is not always easy to separate from it. Chapman has well noted the chief characteristics of the variety, but I may add that in these Gatherings it is distinguished from *C. rotulata* by its compact and robust build, as well as by the characters on which the variety was founded by Reuss. In conclusion I desire to say I am in agreement with Chapman in considering the form as only a variety of *C. rotulata*.

(There seems nothing to be gained by separating this variety from the type.)

220. CRISTELLARIA CULTRATA, (Montfort.)

Robulus cultratus, Montfort, 1808, Conch. Syst., vol. 1, p. 215, 54 genre.
Cristellaria cultrata, Brady, 1884, Chall. Rep., vol. IX, p. 550, pl. LXX, figs. 4-8.

Common in all my Gatherings, but most frequent towards the top of the Marl Beds.

(The carina does not attain any pronounced growth except at Gatherings 2 and 7.)

221. CRISTELLARIA CULTRATA. var. STERNALIS, Berthelin.

Cristellaria sternalis, Berthelin, 1880, Mém. Soc. Géol., France [3], vol. 1, p. 51, pl. III, (XXVI), fig. 2a, b.
C. sternalis, Chapman, 1896, Journ. Roy. Micr. Soc., p. 8, pl. II., fig. 1a, b.

This variety occupies the same position in relation to *C. cultrata* as *C. macrodiscus* does to *C. rotulata*. Under these circumstances it follows that the present form must be reduced from specific to varietal rank. The form is rather rare at Biarritz, but occurs in almost all the Gatherings.

(There seems no more reason for separating this from *C. cultrata* than for separating var. *macrodiscus* from *C. rotulata*.)

222. CRISTELLARIA SUBALATA, Reuss.

Cristellaria subalata, Reuss, 1854, Denkschr. k. Ak. Wiss. vol. VII, (1), p. 68, pl. XXV, fig. 13.

Rather rare, but generally typical and well developed.

(The specimens agree fairly well with the Reuss figures, but the species is not worth separating from *C. cultrata* (Montfort.))

223. CRISTELLARIA DEPAUPERATA, Reuss.

Cristellaria depauperata, Reuss, 1863 (1864), Sitz. k. Ak. Wiss. Wien. vol. XLVIII, (1), p. 66, pl. VI, figs. 67-68; and pl. VIII, fig. 90.

This species can hardly be called rare as it is present in nearly all Gatherings but those taken at the extreme base of the Marl. From one to four specimens were obtained at each of the other stations.

(Reuss himself admits the unsatisfactory and variable specific characters of the species. Halkyard's specimens agree on the whole with the description, but morphologically all the specimens might be described as varieties of either *C. rotulata* or *C. cultrata*, with few and relatively large chambers.)

224. CRISTELLARIA BUDENSIS (Hantken.)

Pl. VI, fig. 2.

Robulina budensis, Hantken, 1875, Mitth. Jahrb. K. ungar. geol. Anst., p. 58, pl. VII, fig. 1.

Robulina budensis, Jones, 1876, Mon. Micr. Journ. vol. XV, pl. CXXVIII, fig. 5.

This variation of the *cultrata* type has not generally been found in all the material collected. It is frequent in Gathering No. 4 (1893) but very rare in, or absent from, the others. The test is compressed, partially evolute, provided with an umbilical boss, and is of delicate growth, with a thin shell-wall.

(This appears to be nothing more than a compressed and depauperate form of *C. cultrata*. Halkyard's specimens are less pauperate than Hantken's figure suggests.)

225. Cristellaria orbicularis (d'Orbigny.)

Robulina orbicularis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 288, pl. VI, figs. 8-9.
Cristellaria orbicularis, Brady, 1884, Chall. Rep., vol. IX, p. 549, pl. LXIX, fig. 17.

Very rare. Found only in the sample of clay brought home in April, 1893, and strangely absent from the larger quantities of Marl collected at later times.

226. Cristellaria wetherellii (Rupert Jones.)

Marginulina wetherellii, Jones, 1854, Morris Catal. Brit. Fossils, ed. 2, p. 37.
Cristellaria wetherellii, Brady, 1884, Chall. Rep., vol. IX, p. 537, pl. CXIV, fig. 14.

The species is frequent in nearly all the Gatherings, but is best developed and most typical at the base of the Marl. In the upper beds the examples are short and delicate in growth, the surface ornamentation is not strong and almost every individual is provided with a thin dorsal keel. Traces of this last feature are also to be found in the more typical specimens.

(This is a fine series of specimens but none of them can be considered as typical as compared with the familiar London Clay types. (S. & C. 1885, etc. M.L.C. p. 652, pl. XV, fig. 18.) The Biarritz specimens are all short, broad, and except for the somewhat turgid cross-section are much more nearly allied to Brady's *C. gemmata* (Chall. Rep. p. 554, pl. LXXI, figs. 6, 7.) than to *C. wetherellii*. In a few of the Biarritz specimens there is a distinct tendency to dimorphic growth, the final chamber being globular, and in one case separated by a short neck from the penultimate chamber.)

227. Cristellaria asperula, Gümbel.
Pl. V. figs. 10, 11.

Cristellaria asperula, Gümbel, 1868, (70). Abh. m.-ph. Cl. k. bayer. Ak. Wiss., vol. X., no description, pl. I, fig. 65a, b.

C. asperula is an elongate, rectilinear, and compressed form allied to *C. wetherellii* from which it is easily separated in the Biarritz Gatherings, there being found no intermediate links. It is not rare.

(Halkyard's specimens do not resemble Gümbel's figure exactly, being more compressed and less strongly decorated. *C. asperula*, Gümbel, like its allies *Marginulina fragraria* Gümbel and *C. cumulicostata*, Gümbel, (all figured on the same plate) are usually regarded as mere synonyms of *C. wetherellii*, and it is almost impossible to separate them. But at Biarritz (*fide* Halkyard) there are no intermediates between the short and broad form which he assigns to *C. wetherellii* and the elongate form for which *fragraria* would be a better type than *asperula*.)

228. CRISTELLARIA CUMULICOSTATA, Gümbel.

Cristellaria cumulicostata, Gümbel, 1868 (70), Abh. m.-ph. Cl. k. bayer, Ak. Wiss., vol. X, p. 638, pl. 1, fig. 67a, b.

Very rare. Only found in Gathering No. 8 (1893). It is allied to *C. wetherellii*, but differs in having the sutures marked by a continuous limbation instead of the tubercles and spines which in the latter species have a tendency to form longitudinal ribs on the surface of the test.

(To attempt to separate species on such trifling grounds, especially in such an extremely variable group, is in our opinion most undesirable.)

SUB-FAMILY POLYMORPHININÆ.

GENUS POLYMORPHINA, d'Orbigny.

229. POLYMORPHINA GIBBA, d'Orbigny.

Polymorphina (*Globulina*) *gibba*, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII. p. 266, No. 20; Modèle. No. 63.
Polymorphina gibba, Brady, 1884, Chall. Rep., vol. IX, p. 561, pl. LXXI, fig. 12a, b.

Frequent; found in most Gatherings. A few small fistulose examples occur in Gathering No. 5, (1893.)

230. POLYMORPHINA LACTEA (Walker & Jacob.)

Serpula lactea, Walker & Jacob, 1898, Adams' Essays Micro., (Kannmacher's edition), p. 634, pl. XIV, fig. 4.
Polymorphina lactea, Brady, 1884, Chall. Rep., vol. IX, p. 559, pl. LXXI, fig. 11, var. fig. 14.

This species is more rare than the last named, but is also widely distributed throughout the Marl beds.

231. Polymorphina lactea. var. oblonga, Williamson.

Polymorphina lactea, var. *oblonga*, Williamson, 1858, Recent Brit. Foram, p. 71, pl. VI, figs. 149-149a.

An exceedingly scarce variety in the Biarritz Marls. I am only able to record one solitary specimen from Gathering No. 8.

232. Polymorphina communis, d'Orbigny.

Polymorphina (*Guttulina*) *communis*, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 266, No. 15. pl. XII, figs. 1-4.
Polymorphina communis, Brady, 1884, Chall. Rep., vol. IX, p. 568, pl. LXXII, fig. 19.

This connecting link between *P. lactea* (W. & J.) and *P. problema*, d'Orb. is rare at the Côte des Basques, specimens were not obtained until the examination of the material collected in 1897.

233. Polymorphina amygdaloides, Reuss.

Globulina amygdaloides, Reuss, 1851, Zeitschr. deutsch. geol. Ges. vol. III, p. 82, pl. VI, fig. 47.
Polymorphina amygdaloides, Brady, 1884, Chall. Rep., vol. IX, p. 560, pl. LXXI, fig. 13.

This is only a flattened variety of *P. lactea*, or perhaps rather of *P. gibba*, as the sutures are generally marked by fine lines and are not depressed. The test is, as a rule, neatly formed and of symmetrical outline, having an oval transverse section. The species is very rare at Biarritz.

234. Polymorphina compressa, d'Orbigny.

Polymorphina compressa, d'Orbigny, 1846, Foram. Foss. Vienne, p. 233, pl. XII, figs. 32-34.
Polymorphina compressa, Brady, 1884, Chall. Rep., vol. IX, p. 565, pl. LXXII, figs. 9-11.

Very rare, and apparently occurring only in the upper half of the Marl.

235. Polymorphina sororia, Reuss.

Polymorphina (*Guttulina*) *sororia*, Reuss, 1863, Bull. Ac. Roy. Belg., [2], vol. XV, p. 151, pl. II, figs. 25-29.
Polymorphina sororia, Brady, 1884, Chall. Rep., vol. IX, p. 562, pl. LXXI, figs. 15-16.

Very rare. The only specimens found are small.

236. POLYMORPHINA LANCEOLATA, Reuss.

Polymorphina lanceolata, Reuss, 1851, Zeitschr. deutsch. geol. Ges. vol. III, p. 83, pl. VI, fig. 50.
Polymorphina lanceolata, Brady, 1884, Chall. Rep., vol. IX, p. 564, pl. LXXII, figs. 5-6.

Rare but small and approaching *P. sororia* Reuss in character.

237. POLYMORPHINA ROTUNDATA (Bornemann.)

Guttulina rotundata, Bornemann, 1855, Zeitschr. deutsch. geol. Ges. vol. VII, p. 346; pl. XVIII, fig. 3.
Polymorphina rotundata, Brady, 1884, Chall. Rep., vol. IX, p. 570, pl. LXXIII, figs. 5-8.

Extremely rare. Only one specimen found in Gathering No. 3.

238. POLYMORPHINA ELEGANTISSIMA, Parker & Jones.

Polymorphina elegantissima, Parker & Jones, 1865, Phil. Trans., vol. CLV, Table X, p. 438.
Polymorphina elegantissima, Brady, 1884, Chall. Rep., vol. IX, p. 566, pl. LXXII, figs. 12-15.

This species is rare in the material collected from the Biarritz Marl and does not attain a large size.

239. POLYMORPHINA COMPLANATA, d'Orbigny.

Polymorphina complanata, d'Orbigny, 1846, Foram. Foss. Vienne, p. 234, pl. XIII, figs. 25-30.
Polymorphina complanata, Brady, Parker & Jones, 1870, Trans. Linn. Soc., vol. XXVII, p. 230, pl. XL, fig. 14a, b.

Very rare. The two specimens found in Gathering No. 7, are rather narrower than d'Orbigny's figures and have the first chamber long and narrow, forming a sort of cauda at the base of the test.

(The two specimens are very distinctive. In their general outline and acuminate base they are much nearer the specimens which we figured from Selsey, (H-A. & E. 1908, etc., S.B. 1909.

p. 432, pl. XVII. figs. 3-5.) than to d'Orbigny's original figure, but they differ from both in the extreme flatness of their faces and their sharply cut angular periphery.)

240. Polymorphina hirsuta, Brady, Parker & Jones.

Polymorphina hirsuta, Brady, Parker & Jones, 1870, Trans. Linn. Soc., vol. XXVII, p. 243, pl. XLII, fig. 37.

Very rare. Found only in Gathering No. 3.

(This adds to the somewhat rare records of this pretty species; the Biarritz specimens are quite typical and well-preserved.)

241. Polymorphina longicollis, Brady.

Polymorphina longicollis, Brady, 1884, Chall. Rep., vol. IX, p. 572, pl. LXXIII, figs. 18-19.

Extremely rare. Only one specimen (a typical one) being found in Gatherings of No. 3 series.

(The specimens are unquestionable, though in a very bad state of preservation. It is essentially a deep water form but has previously been recorded from Tertiary strata.)

242. Polymorphina rugosa, d'Orbigny.

Polymorphina rugosa, d'Orb., 1839, In de la Sagra's Hist. Phisiq. etc., de Cuba, "Foraminifères," p. 138, pl. II; figs. 14-15.

Polymorphina rugosa, Brady, Parker, & Jones, 1870, Trans. Linn. Soc., vol. XXVII, p. 237, pl. XL, figs. 23a—d.

Rare, occurring only in the beds at the end of the Sea-wall. The specimens vary much in size and also in surface ornamentation.

(Halkyard's reference is not strictly correct. D'Orbigny figured two distinct forms under the specific name *rugosa*—one from Cuba as given in Halkyard's reference, the other (*Globulina rugosa* d'Orb.) from Vienna Tertiaries (1846, Foram. Foss. Vienne, p. 229, pl. XIII, figs. 19-20) The Cuba form is, as the author admits, abnormal, a mere sport of *P. compressa* probably. The Vienna form, on the other hand, is a true decorated variety of *P. gibba*, d'Orb. The Biarritz specimens are identical with the Vienna types, and should be referred to them.)

GENUS UVIGERINA, d Orbigny.

243. UVIGERINA PYGMÆA, d'Orbigny.

Uvigerina pygmæa, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 269. pl. XII, figs. 8-9.

Uvigerina pygmæa, Brady, 1884, Chall. Rep., p. 575, pl. LXXIV, figs. 11-12, elongate variety, figs. 13, 14.

A common species and fairly distributed throughout the Marl, but the specimens are only of moderate size.

244. UVIGERINA TENUISTRIATA, Reuss.

Uvigerina tenuistriata, Reuss, 1870. Sitz. k. Ak. Wiss.Wien. vol. LXII, Abth. 1, p. 485; v. Schlicht, Foram. Septar. Pietzpuhl, pl. XXII, figs. 34-37.

Uvigerina tenuistriata, Brady, 1884, Chall. Rep. vol. IX, p. 574 pl. LXXIV, figs. 4-7.

Rather rare, and only found in about half of the samples of washings examined.

(There are a few slender and typical examples but the majority are only depauperate specimens of *U. pygmæa.*)

245. UVIGERINA TENUISTRIATA, var. DEBILIS, nov.

Earlier portion of test similar to that of *U. tenuistriata.* Last chamber, and sometimes the penultimate one, triangular in transverse section. Length, .45 mm.

This variety, of which a fair number of specimens have been found, is a small and evidently weak form of its type, diverging in the direction of *U. angulosa*, Will. It has generally been found in Gatherings in which *U. tenuistriata* does not occur, or is, at any rate, very rare.

(There does not appear to be much reason for the creation of this new variety. *Uvigerina*, when present in material in any abundance, is abnormally subject to variation, and to passage forms between the species. Brady figures many such intermediate specimens. (Chall. Rep. Pls. LXXIV—LXXV.))

246. UVIGERINA ANGULOSA, Williamson.

Uvigerina angulosa, Williamson, 1858, Rec. Brit. Foram., p. 67, pl. V, fig. 140.

Uvigerina angulosa, Brady, 1884, Chall. Rep. vol. IX, p. 576, pl. LXXIV, figs. 15-18.

Well characterised examples are frequent in nearly all the washings examined.

247. Uvigerina canariensis, d'Orbigny.

Uvigerina canariensis, d'Orbigny, 1839, Hist. Nat. Iles Canaries, vol. II, pt. 2, "Foraminifères," p. 138, pl. I, figs. 25-27.
Uvigerina canariensis, Brady, 1884, Chall. Rep., vol. IX, p. 573, pl. LXXIV, figs. 1-3.

Occurs frequently in all Gatherings except No. 1, 1893, where only one minute specimen was found.

248. Uvigerina porrecta, Brady.

Uvigerina porrecta, Brady, 1879, Quar. Journ. Micr. Sci., vol. XIX, p. 274, pl. VIII, figs. 15-16.
Uvigerina porrecta, Brady, 1884, Chall. Rep. vol. IX, p. 577, pl. LXXIV, figs. 21-23.

I have found but few specimens of this small species. The majority of them occurring in the lowest beds of the Marl.

(The specimens are all devoid of any produced neck, and are characterised by an extreme and regular biserial arrangement of the chambers, extending over the greater portion of the test.)

[248a. Uvigerina asperula, Czjzek.]

[*Uvigerina asperula*, Czjzek, 1848, F.W.B., p. 146, pl. XIII, figs. 14-15.
Uvigerina asperula, Brady, 1884, Chall. Rep. vol. IX, p. 578, pl. LXXV, figs. 6-8.]

(A few fairly typical specimens were found on one of the unnamed type slides in the collection.)

SUB-FAMILY RAMULININÆ.

Genus Ramulina, Rupert Jones.

249. Ramulina lævis, Rupert Jones.

Ramulina lævis, Rupert Jones, MS., Wright. Rep. Proc. Belfast, Nat. Field Club, 1873-4, App. III, 1875, p. 88 [90], pl. III, fig. 19.
R. lævis, Chapman, Journ. Roy. Micr. Soc., 1896, p. 582 pl. XII, fig. 2; and ibid, 1898, p. 2, pl. II, fig. 15.

Rare, occurs chiefly in the upper portion of the Marl, only small isolated chambers found.

250. RAMULINA GLOBULIFERA, Brady.

Ramulina globulifera, Brady, 1879, Quart. Journ. Micr. Sci., vol. XIX, p. 272, pl. VIII, figs. 32-33.
R. globulifera, Brady, 1884, Chall. Rep. vol. IX, p. 587, pl. LXXVI, figs. 22-28.

Rather more rare than the last species, and found in similar condition, but in lower horizons. Small.

FAMILY GLOBIGERINIDÆ.

GENUS GLOBIGERINA, d'Orbigny.

251. GLOBIGERINA CONGLOBATA, Brady.

Globigerina conglobata, Brady, 1879, Quart. Journ. Micr. Sci. vol. XIX, p. 286.
G. conglobata, Brady, 1884, Chall. Rep., vol. IX, p. 603, pl. LXXX, figs. 1-5; and pl. LXXXII, fig. 5.

The specimens collected are rather small, and more globular than recent examples, the chambers not being flattened as usual. The supplemental sutural apertures are generally to be seen in the Biarritz specimens. The species is not rare and seems to be most frequent in the middle and lower portions of the Marl, and has not been found at all in the higher Gatherings.

252. GLOBIGERINA BULLOIDES, d'Orbigny.

Globigerina bulloides, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 277, No. 1.
G. bulloides, Brady, 1884, Chall. Rep. vol. IX, p. 593. pl. LXXVII; pl. LXXIX, figs. 3-7.

Frequent, and found in all material examined.

253. GLOBIGERINA DUTERTREI, d'Orbigny.

Globigerina dutertrei, d'Orbigny, 1839. De la Sagra's Hist. Phisiq., etc., de Cuba, "Foraminifères," p. 84, pl. IV, figs. 19-21.
G. dutertrei, Brady, 1884, Chall. Rep. vol. IX, p. 601, pl. LXXXI, figs. 1, a-c.

Typical specimens were noted in almost all Gatherings; but the number of examples is but few altogether.

254. Globigerina inflata, d'Orbigny.

Globigerina inflata, d'Orbigny, 1839, Hist. Iles Canaries, vol. II, (2), "Foraminifères," p. 134, pl. II, figs. 7-9.
G. inflata, Brady, 1884, Chall. Rep., vol. IX, p. 601, pl. LXXIX, figs. 8-10.

Frequent and widely distributed.

255. Globigerina æquilateralis, Brady.

Globigerina æquilateralis, Brady, 1879, Quart. Journ. Micr. Sci., vol. XIX, p. 285.
G. æquilateralis, Brady, 1884, Chall. Rep., vol. IX, p. 605, pl. LXXX, figs. 18-21.

Very rare. Three small specimens found in Gathering 3, (1893.)

(The specimens are very small indeed and evidently existed under extremely unfavourable conditions.)

256. Globigerina dubia, Egger.

Globigerina dubia, Egger, 1857, Neues Jahrbuch fur Min. p. 281, pl. IX, figs. 7-9.
G. dubia, Brady, 1884, Chall. Rep. vol. IX, p. 595, pl. LXXIX, fig. 17a, b, c.

Very rare and small. Occurs only in Gathering 7, 1893.

(The same remark applies to this species.)

256a. [Globigerina cretacea, d'Orbigny.]

[*Globigerina cretacea*, d'Orbigny, 1840, CBP, p. 34, pl. III, figs. 12-14.
G. cretacea, Heron-Allen & Earland, 1914, etc., FKA, 1915, p. 678, pl. LI. figs. 10-13.]

257. Globigerina marginata, (Reuss.)

Rosalina marginata, Reuss, 1845 (6), Verstein. böhm. Kreide, pt. I, p. 36, pl. XIII, fig. 68.
Globigerina marginata, Brady, 1884, Chall. Rep. vol. IX, p. 597, woodcut 17, p. 598.

Very rare and small. Found two examples in Gathering No. 3, (1893.)

(The same remark.)

258. GLOBIGERINA LINNÆANA, (d'Orbigny.)

Rosalina linnæana, d'Orbigny, 1839, De la Sagra's Hist. Phisiq. etc., Cuba, "Foraminifères, p. 101, pl. V, figs. 10-12.
Globigerina. linnæana, Brady, 1884, Chall. Rep., vol. IX, p. 598, pl. CXIV, fig. 21, a, c. Cretaceous specimens, pl. LXXXII, fig. 12, a, b.

Small and rare, the only specimens collected were a few from Gathering 9, (1893.)

(The same remark.)

GENUS ORBULINA, d'Orbigny.

258A. [ORBULINA UNIVERSA, d'Orbigny.]

[*Orbulina universa*, d'Orbigny, 1839, FIC. p. 3, pl. I, fig. 1.
O. universa, Brady, 1884, FC. p. 608, pl. LXXVIII, pl. LXXXI, figs. 8-26. *et seq.*]

GENUS PULLENIA, Parker and Jones.

259. PULLENIA QUINQUELOBA, (Reuss.)

Nonionina quinqueloba, Reuss, 1851, Zeitschr. deutsch. geol. Ges.., vol. III, p. 71, pl. V, fig. 31.
Pullenia quinqueloba, Brady, 1884, Chall. Rep., vol. IX, p. 617, pl. LXXXIV, figs. 14, 15.

Specimens are small and rare, and occur principally in the middle part of the Beds.

GENUS SPHAEROIDINA, d'Orbigny.

259A. [SPHAEROIDINA BULLOIDES, d'Orbigny.]

[*Sphaeroidina bulloides*, d'Orbigny, 1826, Ann. Sci. Nat.; vol. VII, p. 267, No. 1; Modèle, No. 65.
S. bulloides, Brady, 1884, FC. p. 620, pl. LXXXIV, figs. 1-7.]

FAMILY ROTALIDÆ.

SUB-FAMILY SPIRILLININÆ.

GENUS SPIRILLINA, Ehrenberg.

260. SPIRILLINA VIVIPARA, Ehrenberg.

Spirillina vivipara, Ehrenberg, 1841, Abhandl. k. Ak. Wiss. Berlin, p. 442, pl. III, fig. 41.
Spirillina vivipara, Brady, 1884, Chall. Rep., vol. IX, p. 630, pl. LXXXV, figs. 1-5.

Not rare and evenly distributed but small and weak.

260A. [SPIRILLINA MARGARITIFERA, Williamson.]

[*Spirillina margaritifera*, Williamson, 1858, RFGB, p. 93, pl. VII, fig. 204.
S. margaritifera, Heron-Allen & Earland, 1914, etc. FKA, 1915, p. 685.]

261. [SPIRILLINA SELSEYENSIS, Heron-Allen & Earland.]

[*Spirillina selseyensis*, Heron-Allen & Earland, 1908, etc., S.B. 1909, p. 440, pl. XVIII, figs. 6, 7.]

261A. SPIRILLINA RESTIS, sp. nov.

Pl. VI, fig. 6, and Pl. VII, fig. 8.

Test consisting of a plano-spiral tube of about five convolutions, increasing slowly in width, tube not symmetrical in section, consequently one lateral surface of the test is larger than the other, the larger surface ornamented with oblique elongate tubercles, the opposite surface without ornamentation except a septal limbation. Diam. .35 mm.

This new species is very rare, and is perhaps only an extreme development of Williamson's *S. margaritifera*. I have found one or two specimens which tended in the direction of Brady's *S. inæqualis*, but, as the latter seems not to be a *Spirillina* (see the apertures in Brady's figures), it has been thought best to include them with the better-marked specimens in the present species. The specimen figured on Plate VII only shows slight traces of the oblique corrugations of the whorls.

(This appears to be identical with our previously recorded species *S. selseyensis* from similar material from Selsey. Our name having priority must stand.)

262. SPIRILLINA LIMBATA, Brady.

Spirillina limbata, Brady, 1879, Quart. Journ. Micr. Sci., vol. XIX. pl. VIII, fig. 26, a, b.
Spirillina limbata, Brady, 1884, Chall. Rep., vol. IX. p. 632, pl. LXXXV, figs. 18-21.

Very rare. Three damaged specimens found in the beds exposed between tide-marks near the end of the Quai des Basques.

SUB-FAMILY ROTALINÆ.

GENUS PATELLINA, Williamson.

263. PATELLINA CORRUGATA, Williamson.

Patellina corrugata, Williamson, 1858, Rec. Brit. Foram., p. 46, pl. III, figs. 86-89.
P. corrugata, Brady, 1884, Chall. Rep., vol. IX, p. 634, pl. LXXXVI, figs. 1-7.

Very rare, small, and delicate.

(The specimens although few in number are very remarkable, for they include not merely the original type of Williamson, which is the sole representative of this species at G.3 but also the peculiar flat discoid type now typical of Australian shore-gatherings, which occurs in G. 8 and 9. This has been figured by Chapman. (C. 1907. R.F.V. p. 134, pl. X, fig. 7.))

264. [CHAPMANIA GASSINENSIS, Silvestri.]

[*Chapmania gassinensis*, Silvestri, Atti. Pont. Ac. N. Lincei, Ann. 4. viii. (1904-5), p. 130.]

264A. PATELLINA CONICA, sp. nov.

Pl. VI, fig. 7, and Pl. VIII, figs. 6-7.

Test conical with rounded apex, inferior face flat, peripheral edge obtuse. External or cortical layer consisting of numerous small chambers arranged at first in spiral whorls, latterly in concentric rings. Hollow central portion of test filled with perforated horizontal lamellæ which are connected with one another by short vertical columns. Diam. 1.1 mm. Height, .9 mm.

This new species is rare, and hitherto has only been found in material collected from sandy and shelly veins in the beds exposed between tide-marks at the end of the Quai des Basques. The form is a well developed one and displays all the characteristics of the genus, but instead of large chambers sub-divided into chamberlets by transverse partitions, the cortical layer consists of numerous small chambers of square or rectangular section, and with a rounded apex which is pointed towards the vertical axis of the test, and at right angles to it. In a fortuitously broken specimen I have observed the globular primordial chamber which is followed by two arc-shaped ones, this form gradually gives place to the "obelisk" form. The first

horizontal whorl surrounding the primordial cell consists of six chambers. The arrangement of the chambers cannot be seen in unabraded specimens owing to the opacity and smoothness of the exterior surface of the test. The perforations of the central horizontal laminæ are irregularly disposed and so are the vertical connecting columns.

Fig. 6, Plate VI, shows well the transverse section of the cortical chambers. Fig. 7, Plate VIII, the longitudinal section of the same, as well as the construction of the shell-matter occupying the interior of the hollow cone formed by those chambers.

I would wish to remark that the drawings given here are made from actual specimens and are in no sense reconstructions.

(Halkyard's species is represented in the collection by specimens on the type slides and by a balsam mount containing three vertical sections taken in different planes. The available specimens therefore are sufficient, in connection with his drawings, to connect the species with *Chapmania gassinensis*, Silvestri. The measurements, size and shape of the chamberlets all agree fairly closely with that form. The species has been thoroughly analysed and discussed (together with its isomorph *Dictyoconus ægyptiensis*) by Silvestri in the *Rivista Italiana di Paleontologica* (Ann. XI, 1905, Pt. III, pp. 113-120, pl. II.)

Halkyard's forms appear to be more bluntly conical than Silvestri's, and the basal edge in consequence less acutely angular. It will be observed that Halkyard gives as locality for his specimens "material collected from sandy and shelly veins in the beds exposed between tide-marks." This does not altogether exclude the possibility of their being derived fossils washed from some earlier or later horizons than the other Biarritz specimens, and a note among the Halkyard MSS. shows that he inclined to this opinion himself.)

[HALKYARDIA, GEN. NOV.]

Genus Linderina, Schlumberger.

"Test discoidal, thickened at the centre, composed of a single rank of numerous little chambers disposed circularly round a central chamber and in the same plane. The walls of each chamber are prolonged towards the middle above the chambers already formed. This calcareous envelope is traversed by large perforations which penetrate directly to the internal chambers."

The above is the generic description given by Schlumberger in "Note sur les genres *Trillina* et *Linderina*" (Bull. Soc. Géol. de France, 3e serie, tome XXI (1893), p. 120), and requires some modification to include such members of the genus as the two new ones described below which undoubtedly must be classed in the same genus. The only species described by Schlumberger (*L. brugesii*) differs slightly from his generic description inasmuch as the chambers are not all in the same horizontal plane, the disc of chambers being slightly hollowed on the inferior surface, if one disregards the prolongations of the chamber-wall which cover the previously formed rows of cells and cause the thickening of the central portion of the disc. This hollowing of the inferior surface, which is noted by Schlumberger in his description of *L. brugesii*, is carried to such an extent in my *L. chapmani* as to produce a test similar in appearance to *Patellina*, or some forms of *Cymbalopora* with which latter genus *Linderina* is closely allied, the shell-wall in both genera being of the same character, and both forms having a small spiral commencement to the test followed by concentric rows of chambers, the cells of each row alternating with those of the previous row, so that the centre of each chamber is opposite the point of junction of two chambers of the preceding ring, after the manner of *Planorbulina* and *Cymbalopora*.

In my opinion, after careful study of specimens of *L. ovata* mounted in Canada Balsam, Schlumberger is mistaken in affirming that "the wall of all the chambers is continuous on all the circumference, without any trace of suture, and is corrugated in order to form each of the little chambers." I have observed this apparent duplication and corrugation of the cell wall which can only be seen in very few cells of the many composing a single test, and am satisfied that it can be accounted for in other ways such as cutting through the apertural pores of adjoining chambers. In the vast majority of cases the cells are arranged on the planorbuline plan, and consequently there is a well-defined suture.

I must also remark that Schlumberger's photogravure (Fig. 7, Plate 3, representing a transverse section of a test), does not show the double shell-wall, neither does his wood cut on page 121, which I reproduce here (Plate VII, fig. 1.)

Schlumberger's specimens were collected from the Upper Eocene deposits at Bruges (Gironde).

(Halkyard does not appear to have had personal acquaintance with any specimens of Schlumberger's Genus *Linderina*.

otherwise he could hardly have confused his very distinctive types with Schlumberger's. We have not attempted to modify the generic definition of *Linderina* in order to bring them in. The differences are too wide and deep for reconcilement, and we have found it necessary to institute a new genus for Halkyard's forms, which we have pleasure in associating with his memory under the name *Halkyardia*.

We have had a great advantage in having previously become fully acquainted with the structure of Schlumberger's *Linderina brugesii* in the numerous examples of the species which we identified, described and figured exhaustively in our Selsey Monograph (H-A. & E. 1908, etc. S.B. 1911. p. 332. pl. XII, figs. 1-7.) We fully confirm the diagnosis of Schlumberger, which Halkyard disputes.

The essential differences between *Halkyardia* and *Linderina* can be briefly explained. In *Linderina* we have a shell with a horizontal series of planorbuline chambers. These chambers by successive thickenings of the external wall eventually result in a biconvex disc which, if cut in median section, shows a thick wall in the centre of the disc decreasing in thickness to each edge. The disc is usually somewhat "dished" instead of being symmetrically biconvex. In *Halkyardia* on the other hand the planorbuline disc of chambers, concave in cross section, tends to fill up the concavity with a mass of shell substance perforated with numerous canals. Seen in section the thickening is confined to the concave side only. Both in shell structure and arrangement of chambers, *Halkyardia* is clearly very closely related to *Planorbulina* and *Cymbalopora*.)

265. [Halkyardia ovata, sp. nov.]

265a. Linderina ovata, sp. nov.

Pl. VI, figs. 10-12.

Test depressed, ovate; superior surface slightly convex, inferior surface flat; composed of numerous small chambers, the first four or five of which are arranged in a spiral manner; the later ones disposed on either side of a series occupying the longitudinal axis of the shell. Only the outside row of chambers visible externally. Aperture porous, as in *Cymbalopora*, or sometimes consisting of one or two larger openings. Length .66 mm., breadth .35 mm.

Apart from the external form, being ovate and not circular, this species shows all the characteristics of *L. brugesii*, Schlumberger. The form of the chambers,the shell-wall, and the external appearance and structure of the thickened central portion are absolutely identical. The young shell is spicular or fusiform, the long axis being sometimes five times as long as the shorter one, whilst in the most highly developed test I have met with (fig. 10) the proportion is less than two to one. This seems to show that the cells on the long axis are at first developed more rapidly than the lateral ones, but, after a certain stage is reached, their increase is arrested and the lateral chambers gain the ascendency, so that it is quite possible that in time a discoidal shell like Schlumberger's species might be produced.

This species is not common, but I have collected from eight samples of the Blue Marl, 30 or 35 specimens.

(Apart from Halkyard's efforts to bring the description of this species within the definitions of *Linderina* the foregoing remarks present nearly all that can be said for this very curious form. Viewed from the superior surface, both species of *Halkyardia* might readily be mistaken for *Cymbalopora poeyi* (d'Orb.) of the depressed type; only when the under surface is viewed does the secondary deposit in the umbilical recess give the clue to its distinctive structure.)

266. [HALKYARDIA MINIMA, (Liebus.)]

[*Cymbalopora radiata*, Hagenow, var. *minima*, Liebus, 1911, Sitzb. k. Akad. Wiss. Wien. Math. nat. Kl. vol. CXX, Abth. 1, 1911, p. 952, pl. III, fig. 7.]

266A. LINDERINA CHAPMANI, sp. nov.

Pl. VI, figs. 8, 9.

Test conical, with rounded apex, formed of concentric rows of wedge-shaped chambers. Centre of hollow cone filled up by prolongations of the inferior walls of the cells. The superior surface of the test thickened by the prolongation of the superior chambers-walls. Diam..6 mm. Height .3 mm.

This very beautiful species shows clearly by the form and arrangement of its chambers its relationship to *Cymbalopora;* it is however more regular in structure and of a higher type. A vertical section (fig. 9, pl. VI) shows plainly by the varying

angle of the chambers in respect to the vertical axis of the shell, the evolution of the conical form of the mature test from the lenticular shape of the young shell.

This species is rarer than the preceding one, only half the number of specimens being noted from six Gatherings of Marl.

I have much pleasure in associating Mr. F. Chapman's name with this interesting form, in grateful remembrance of the valuable assistance he has so willingly afforded me in overcoming the difficulties which I have encountered in my work on the collections now under consideration.

(Halkyard's intention of naming this new species after Frederick Chapman cannot unfortunately be carried out, inasmuch as the form has already been described and figured as above, though Liebus misunderstood the structure of the test and referred his specimens to the genus *Cymbalopora* of Hagenow. In this species there is a limited amount of thickening of the shell wall on the superior side, thus perhaps affording evidence of some relationship between *Linderina* and the new genus *Halkyardia*, but the superior thickening is very limited in extent and is as coarsely perforate as on the inferior side. The species is absolutely indistinguishable from depressed specimens of *Cymbalopora poeyi*, (d'Orb.) when viewed from the superior surface.)

Genus Discorbina, Parker & Jones.

267. Discorbina obtusa, (d'Orbigny.)

Rosalina obtusa, d'Orbigny, 1846, Foram. Foss. Vienne, p. 179, pl. XI, figs. 4-6.
Discorbina obtusa, Brady, 1884, Chall. Rep., Vol. IX, p. 644, pl. XCI, fig. 9a, b, c?

The specimens found in my collections are both small and rare.

268. Discorbina allomorphinoides, (Reuss.)

Valvulina allomorphinoides, Reuss, 1860, Sitz. k. Ak. Wiss. Wien. vol. XL, p. 223, pl. XI, fig. 6, a-c.
Discorbina allomorphinoides, Brady, 1884, Chall. Rep., vol. IX, p. 654, pl. XCI, figs. 5, 8.

This species is more frequent than *D. obtusa* and attains somewhat larger dimensions, though it can hardly be said to be very well developed in the Blue Marl.

269. DISCORBINA SAULCYI, (d'Orbigny.)

Rosalina saulcyi, d'Orbigny, 1839, Voyage Amér. Mérid., vol. V. pt. 5, "Foraminifères," p. 42, pl. II, figs. 9-11.
Discorbina saulcyi, Brady, 1884, Chall. Rep., vol. IX, p. 653, pl. XCI, figs. 6a, b, c.

Small and rare but fairly well distributed.

270. DISCORBINA VILARDEBOANA, (d'Orbigny.)

Rosalina vilardeboana, d'Orbigny, 1839, Voyage Amér. Mérid., vol. V, pt. 5, "Foraminfères," p. 44, pl. VI, figs. 13-15.
Discorbina vilardeboana, Brady, 1884, Chall. Rep., vol. IX, p. 645, pl. LXXXVI, figs. 9, 12; and pl. LXXXVIII, fig. 2.

Very rare, only two small specimens found in the whole of the samples of Marl examined.

271. DISCORBINA RUGOSA, (d'Orbigny.)

Rosalina rugosa, d'Orbigny, 1839, Voyage Amér. Mérid., vol. VI, pt. 5, "Foraminifères," p. 42, pl. II, figs. 12-14.
Discorbina rugosa, Brady, 1884, Chall. Rep., vol. IX, p. 652, pl. LXXXVII, figs. 3a, b, c, and pl. XCI, fig. 4a, b, c.

Rare and small, it seems to be limited to the upper portion of the Marl.

(The specimens can hardly be described as typical.)

272. DISCORBINA GLOBULARIS, (d'Orbigny.)

Rosalina globularis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 271, No. 1, pl. XIII, figs. 1-4.
Discorbina globularis, Brady, 1884, Chall. Rep., vol. IX., p. 643, pl. LXXXVI, figs. 8, 13.

Rare, but fairly distributed, specimens typical and well developed.

(The specimens are all of the thick-walled highly perforate type.)

273. DISCORBINA OPERCULARIS, (d'Orbigny.)

Rosalina opercularis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 271, No. 7.
Discorbina opercularis, Brady, 1884, Chall. Rep. vol. IX, p. 650, pl. LXXXIX, figs. 8, 9.

This form requires no special remark except that it is rare and occurs chiefly in the lower beds.

274. Discorbina opercularis, var. elegans, nov.

Pl. VII, fig. 2

This variety differs from the type in its invariably smaller dimensions, neater build, broader and less arched chambers, and the lesser and more gradually increasing width of its spiral whorls. The drawing given here represents well the characteristics described above. Diam. .3 mm.

The variety is rare and not always accompanied by its type species.

(The variety would not appear to be worth separating. It probably only represents a depauperate form of the type existing under unfavourable conditions.)

275. Discorbina pileolus, (d'Orbigny.)

Valvulina pileolus, d'Orbigny, 1839, Voyage Amér. Mérid., vol. V, pt. 5, "Foraminifères," p. 47, pl. I, figs. 15-17.
Discorbina pileolus, Brady, 1884, Chall. Rep., vol. IX, p. 649, pl. LXXXIX, figs. 2-4.

Very rare; two small specimens found in the lowest soft beds of the Marl.

276. Discorbina concinna, Brady.

Discorbina concinna, Brady, 1884, Chall. Rep., vol. IX, p. 646, pl. XC, figs. 7-8.

Very rare, only two small specimens noted.

277. Discorbina rosacea, (d'Orbigny.)

Rotalia rosacea, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 273, No. 15.
Discorbina rosacea, Brady, 1884, Chall. Rep., vol. IX, p. 644, pl. LXXXVII, figs. 1, 4.

Rare and small.

278. Discorbina orbicularis, (Terquem.)

Rosalina orbicularis, Terquem, 1876, Ess. Anim. Plage Dunkerque, pt. 2, p. 75, pl. IX, fig. 4a. b.
Discorbina orbicularis, Brady, 1884, Chall. Rep., vol. IX, p. 647, pl. LXXXVIII, figs. 4-8.

Less rare than the last species but still not frequent.

279. DISCORBINA COMPRESSA, sp. nov.

Pl. VII, fig. 3.

Shell compressed, thin, flattened on both surfaces, peripheral edge sharp, generally keeled. Test composed of about sixteen arched chambers. The sutures and spiral line of earlier chambers limbate on superior surface, which is also decorated with scattered tubercles. Inferior surface smooth except for a few tubercles occupying the centre of the disc. Diam. 1.0 mm.

The species is rather rare but is easily distinguished from the other members of the genus. When unaltered by erosion, etc., the shell is seen to be thin and semi-transparent with comparatively large pores. In the specimen figured the last chamber is fractured. I draw attention to this fact to avoid all possibility of misinterpretation of my drawing.

(Halkyard's drawing shows a feature which is not referred to in the description but which is certainly one of the most striking points in the species, viz., the prominence of the secondary, or asterigerine, series of chambers which are exposed on the superior surface of the test, but invisible on the inferior, contrary to the usual order of things. It is assumed that the carinate edge marks the inferior face, as in other species.)

280. DISCORBINA GLOBIGERINOIDES, Parker & Jones.

Discorbina globigerinoides, Parker & Jones, 1865, Phil. Trans., p. 385 & 421, pl. XIX, figs. 7a, b, c.

Extremely rare. A single well-grown specimen only having been found.

(The specimen is an infiltrated fossil, and we cannot satisfy ourselves as to its identity.)

GENUS PLANORBULINA, d'Orbigny.

281. PLANORBULINA MEDITERRANENSIS, d'Orbigny.

Planorbulina mediterranensis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 280, pl. XIV, figs. 4-6.

Planorbulina mediterranensis, Brady, 1884, Chall. Rep., vol. IX, p. 656, pl. XCII, figs. 1-3.

Very rare. Two small broken specimens from the upper part of the Marl.

SUB-FAMILY TINOPORINÆ.

Genus Gypsina, Carter.

282. Gypsina inhærens, (Schultze.)

Acervulina inhærens, Schultze, 1854, Organismus Polythal, p. 68, pl. VI, fig. 12.
Gypsina inhærens, Brady, 1884, Chall. Rep., vol. IX, p. 718, pl. CII, figs. 1-6.

Very rare. Four specimens noted.

(Both of the specimens on the principal slide, should be referred to *G. vesicularis* (P. & J.). Two other similar specimens occur on another slide. The genus occurs in this place in Halkyard's MS., but should come in after Pulvinulina.)

283. Gypsina globulus, (Reuss.)

Ceriopora globulus, Reuss, 1847. Haidinger's Nat. Abh. II, p. 33, pl. V, fig. 7.
Gypsina globulus, Brady, 1884, Chall. Rep., vol. IX, p. 717, pl. CI, fig. 8.

Extremely rare. A single typical specimen was found in material collected at the top of the cliff about 200 yards south of the villa known as l'Ermitage.

284. Gypsina vesicularis, (Parker & Jones.)

Orbitolina vesicularis, Parker & Jones, 1860, Ann. Mag. Nat. Hist., [3], vol. VI, p. 31.
Gypsina vesicularis, Brady, 1884, Chall. Rep., vol. IX, p. 718, pl. CI, figs. 9-12.

Extremely rare. The solitary specimen found is almost globular in form, there being slight flattening and depression on one portion which seems to have been the point of attachment to some foreign body. This feature is the only difference between this specimen and the one assigned to *G. globulus*, and it is doubtful whether it would not be better to assign both specimens to the latter species. It may be remarked that the two examples were found in widely separated horizons of the Marl.

(See No. 282.)

GENUS CARPENTERIA, Gray.

285. CARPENTERIA PROTEIFORMIS, Göes.

Carpenteria balaniformis, var. *proteiformis*, Göes, 1882, K. Svenska Vet.-Akad. Handl. XIX, No. 4, p. 94, pl. VI, figs. 208-214; pl. VII, figs. 215-219.

Carpenteria proteiformis, Brady, 1884, Chall. Rep., vol. IX, p. 679, pl. XCVII, figs. 8-14.

Very rare. Only three fragments found.

(See our note upon this species *sub* Columella, No. 50, *note*.)

GENUS TRUNCATULINA, d'Orbigny.

286. TRUNCATULINA HAIDINGERII, (d'Orbigny.)

Rotalina haidingerii, d'Orbigny, 1846, Foram. Foss. Vienne, p. 154, pl. VIII, figs. 7-9.

Truncatulina haidingerii, Brady, 1884, Chall. Rep., vol. IX, p. 663, pl. XCV, fig. 7a, b, c.

This species is common in most of my Gatherings, and the specimens as a rule are robust and typical.

(There is a considerable range of variation in the large series of specimens selected, many of them being almost flat on the inferior side.)

287. TRUNCATULINA UNGERIANA, (d'Orbigny.)

Rotalina ungeriana, d'Orbigny, 1846, Foram. Foss. Vienne, p. 157, pl. VIII, figs. 16-18.

Truncatulina ungeriana, Brady, 1884, Chall. Rep., vol. IX, p. 664, pl. XCIV, fig. 9a, b, c.

Occurs chiefly in the middle and lower portions of the Marl. The examples found are generally well-developed, but are not numerous.

287a. [TRUNCATULINA AKNERIANA (d'Orbigny).]

[*Rotalina akneriana*, d'Orbigny, 1846, FFV, p. 156, pl. VIII, figs. 13-15.

Truncatulina akneriana, Brady, 1884, FC. p. 663, pl. XCIV. fig. 8, a, b, c.]

288. TRUNCATULINA LOBATULA, (Walker & Jacob.)

Nautilus lobatulus, Walker & Jacob, 1798. In Kannmacher's ed. of Adam's Essays Micros., p. 642, pl. XIV, fig. 36.

Truncatulina lobatula, Brady, 1884, Chall Rep., vol. IX, p. 660, pl. XCII, fig. 10, pl. XCIII, figs. 1, 4, 5; pl. CXV, figs. 4-5

Specimens frequent and well distributed. Tending in form towards *T. ungeriana* rather than towards the irregular, wild-growing form *T. variabilis*, d'Orb.

[288A. TRUNCATULINA REFULGENS. (Montfort.)]

[*Cibicides refulgens*, Montfort, 1808-10, CS. vol. 1, p. 122, 123, 31 me. genre.
Truncatulina refulgens, Brady, Chall. Rep., vol. IX, p. 659, pl. XCII, figs. 7-9.]

[Several specimens were found on one of the unnamed type slides. See also note to No. 297.]

289. TRUNCATULINA WUELLERSTORFI, (Schwager.)

Anomalina wüllerstorfi, Schwager, 1866. Novara Exped., Geol. II, p. 258, pl. VII, figs. 105-107.
Truncatulina wuellerstorfi, Brady, 1884, Chall. Rep., vol. IX, p. 662; pl. XCIII, figs. 8-9.

Rather rare and found only in the upper beds of the Côte des Basques.

290. TRUNCATULINA ROBERTSONIANA, Brady.

Truncatulina robertsoniana, Brady, 1881, Quart. Journ. Micr. vol. XXI, p. 65.
T. robertsoniana, Brady, 1884, Chall. Rep. vol. IX, p. 664, pl. XCV, fig. 4a, b, c.

Examples are not very rare but are small and weak, showing that the conditions under which they lived were not suitable to the development of the species. Of the three localities from which Brady's specimens came, two are in the West Indies, and the third off Pernambuco, S. America. The depths recorded are from 390 to 675 fathoms.

(Very few of the specimens can be regarded as typical. The bulk of them are much more angular in periphery and tend in the direction of *T. ungeriana*.)

291. TRUNCATULINA RETICULATA, (Czjzek.)

Rotalina reticulata, Czjzek, 1848, Haidinger's Nät. Abh. II, p. 145, pl. XIII, figs. 7-9.
Truncatulina reticulata, Brady, 1884, Chall. Rep., vol. IX p. 669, pl. XCVI, figs. 5-8.

Frequent and fairly distributed, the species however becomes rare in the lower Marl beds. The examples found are small but typical.

292. TRUNCATULINA TENERA, Brady.

Truncatulina tenera, Brady, 1884, Chall. Rep., vol. IX, p. 665, pl. XCV, fig. 11a, b, c.

Specimens few but well grown. The species can easily be distinguished from its isomorph *Pulvinulina umbonata*, Reuss, by the different character of its oral aperture, which, in the latter, is without the raised margin so general in the genus *Truncatulina*. The shell-wall is also another point of difference between the two genera, being much smoother and with finer pores in *Pulvinulina* than in *Truncatulina*.

(The shell wall is rougher and much more coarsely perforated than in recent types.)

293. TRUNCATULINA PYGMÆA, Hantken.

Pulvinulina pygmæa, Hantken, 1875, Mittheil Jahrb., d. k. ung. geol. Anstalt, vol. IV, p. 78, p. X, fig. 8. (*Truncatulina pygmæa* on plate.)

T. pygmæa, Brady, 1884, Chall. Rep. vol. IX, p. 666, pl. XCV, figs. 9-10.

Very rare. Only two specimens found, both in the same sample of Marl (No. 4.)

294. TRUNCATULINA TENUIMARGO, Brady.

Truncatulina tenuimargo, Brady, 1884, Chall. Rep., vol. IX, p. 662, pl. XCIII, figs. 2-3.

Rare. The examples found are somewhat irregular in growth, the superior face being generally concave in full-grown specimens and the last two chambers often very deformed. The texture of the shell is smooth, and the sutures and peripheral edge thickened and glassy.

(The specimens can only be referred to this variety by considerable latitude of identification. They are merely *T. lobatula* with a somewhat prominent marginal edge; there is no definite keel.)

295. TRUNCATULINA HUMILIS, Brady.

Truncatulina humilis, Brady, 1884, Chall. Rep., vol. IX, p. 665, pl. XCIV, fig. 7a, b, c.

Very rare. Three specimens found in a single sample of Marl (No. 3.)

(Brady's species in itself, is on the author's admission, very obscure, and we should prefer to regard Halkyard's few specimens merely as immature stages of some other truncatuline species, possibly *T. robertsoniana*, Brady.)

296. Truncatulina culter, (Parker & Jones.)

Planorbulina culter, Parker & Jones, 1865, Phil. Trans., p. 421, pl. XIX, fig. 1.
Truncatulina culter, Brady, 1884, Chall. Rep., vol. IX, p. 668, pl. XCVI, fig. 3, a, b, c.

Very rare. One small, and two well-grown, examples were noted.

Genus Anomalina, Parker & Jones.

297. Anomalina grosserugosa, (Gümbel.)

Truncatulina grosserugosa. Gümbel, 1868 (1870), Abhandl. d. k. bayer Akad. Wiss., II, Cl. vol. X, p. 660, pl. II, fig. 104. a, b.
Anomalina grosserugosa, Brady, 1884, Chall. Rep., vol. IX, p. 673, pl. XCIV, figs. 4-5.

Not rare. Specimens strong, but hardly typical, approaching in some cases very near to *T. lobatula*.

(Halkyard's specimens are not by any means satisfactory by reference to this species. They are all angular in periphery and should, we think, be referred to *T. lobatula* and *T. refulgens*. On a type slide in the collection is a single specimen which may possibly be referred to this species, but it is broken and in a very much worn condition. In life the specimen must have attained comparatively gigantic proportions, the portion remaining measures 2.5mm. in diameter. On another type slide however, are several specimens which we think correctly identified, but are not typical. They are very large and the angular periphery on the inferior side tends to approach *Anomalina coronata*, P. & J.)

298. Anomalina ammonoides, (Reuss.)

Rosalina ammonoides, Reuss, 1845, Verstein. böhm. Kreid., pt. I, p. 36, pl. VIII, fig. 53; and pl. XIII, fig. 66.
Anomalina ammonoides, Brady, 1884, Chall. Rep., vol. IX, p. 672, pl. XCIV, figs. 2-3.

Occurs frequently throughout the whole extent of the Marl beds.

(A large and variable series of specimens ranging from smooth types with excavate umbilici, to strongly developed limbate varieties, with a prominent solid umbilicus.)

299. ANOMALINA CORONATA, Parker & Jones.

Anomalina coronata, Parker & Jones, 1857, Ann. Mag. Nat. Hist. ser. 2, vol. XIX, p. 294, pl. X, figs. 15-16.
A. coronata, Brady, 1884, Chall. Rep., vol. IX, p. 675, pl. XCVII, figs. 1-2.

Very rare. Two small examples found in different Gatherings of the Marl.

(Neither of the two small specimens can be regarded as typical or satisfactory, although probably referable to this species. See note to 297.)

300. ANOMALINA ARIMINENSIS, (d'Orbigny.)

Planulina ariminensis, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 280, pl. IV, figs. 1-3 bis.
Anomalina ariminensis, Brady, 1884, Chall. Rep. vol. IX, p. 674, pl. XCIII, figs. 10-11.

Rather rare. The greatest number of specimens occurred in a Gathering from the lower beds.

[300A. ANOMALINA FOVEOLATA, Brady.]

[*Anomalina foveolata*, Brady, 1884, Chall Rep., vol. IX, p. 674, pl. XCIV, fig. 1a, b, c.]

[On one of the type slides in the collection listed under *Anomalina ariminensis* we have found some specimens which though differing somewhat from Brady's type should be referred to this species. The shells are remarkably well preserved and the sculpturing very strongly marked. We have also found several specimens in the hitherto unexamined material.]

GENUS PULVINULINA, Parker & Jones.

301. PULVINULINA ACUTIMARGO, sp. nov.

Plate VII, fig. 4.

Test free, rotaliform, both faces convex, the inferior slightly more so than the superior, periphery sharp, lobated; consisting of three convolutions, the last of which is formed of five chambers. Sutures non-limbate, excavated on the inferior surface, flush on the superior surface of the test. Aperture large and conspicuous. Diam, .7 mm.

This new species belongs to the *menardii* group, but is smooth and glassy in texture thus differing from the other members of that group. The example figured here is a typical

one but specimens are frequently found in which the superior surface is less convex than in my drawing. The species is not rare, in fact is found in nearly all the samples of Marl examined.

(The species is allied to the *P. elegans*, not to the *P. menardii* group.)

301A. [PULVINULINA MENARDII (d'Orbigny).]

[*Rotalia menardii*, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 273, No. 26, Modèle No. 10.
Pulvinulina menardii, Brady, 1884, FC. p. 690, pl. CIII, figs. 1-2.]

301B. [PULVINULINA MENARDII, var. FIMBRIATA, Brady.]

[*Pulvinulina menardii*, var. *fimbriata*, Brady, 1884, FC. p. 691, pl. CIII, fig. 3, a. b.]

302. PULVINULINA CRASSA, (d'Orbigny.)

Rotalina crassa, d'Orbigny, 1840, Mém. Soc. Géol. France, vol. IV, p. 32, pl. III, figs. 7-8.
Pulvinulina crassa, Brady, 1884, Chall. Rep., vol. IX, p. 694, pl. CIII, figs. 11-12.

Rare. Three small specimens found in the Gathering taken from the highest level of the beds.

303. PULVINULINA KARSTENI, (Reuss.)

Rotalia karsteni, Reuss, 1855, Zeitschr. d. deutsch. geol. Ges. vol. VII, p. 273, pl. IX, fig. 6.
Pulvinulina karsteni, Brady, 1884, Chall. Rep., vol. IX, p. 698, pl. CV, figs. 8-9.

Rather rare and variable and occurring somewhat irregularly in the majority of the Gatherings.

(Very few of the specimens can be regarded as typical.)

304. PULVINULINA KARSTENI, var. PARVA, nov.

Plate VII, fig. 5.

Test, rotaliform, inferior surface flatter than the superior one, periphery obtuse and entire; composed of three to three-and-a-half whorls, the last of which consists of 9 or 10 segments, sutures flush on superior, depressed on inferior surface, centre of inferior surface occupied by a small but deep umbilical depression. Diam. .25 mm.

This variety is very rare, but as several specimens have been noticed which answer closely to the above figures and description, it is safe to assume that this particular form is worthy of being noticed. It is much smaller than the type species, and more neatly built, the whorls being narrow and the segments numerous. The peripheral edge is also more rounded than in *P. karsteni* from the same Gatherings.

(A memorandum found among the Halkyard MSS. tells us that the specimens have been lost.)

305. PULVINULINA REPANDA, (Fichtel & Möll.)

Nautilus repandus, Fichtel & Moll., 1803. Test. Micr., p. 35, pl. III, figs. a-d.
Pulvinulina repanda, Brady, 1884, Chall. Rep., vol. IX, p. 684, pl. CIV, fig. 18, a, b, c.

Not rare. A few specimens found in nearly all samples examined though the species is more rare in some than in others.

306. PULVINULINA BOUEANA, (d'Orbigny.)

Rotalina boueana, d'Orbigny, 1846, Foram. Foss. Vienne, p. 152, pl. VII, figs. 25-27.
Pulvinulina boueana, Sherborn & Chapman, 1886, Journ. Roy. Micr. Soc., [2], pt. VI, p. 758, pl. XVI, fig. 20, a-c.

Very rare. Only two examples, both found in the same Gathering from about the centre of the Marl beds.

(The specimens appear to be young *P. repanda*.)

307. PULVINULINA ELEGANS, (d'Orbigny.)

Rotalia elegans, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 272, No. 6.
Pulvinulina elegans, Brady, 1884, Chall. Rep., vol. IX p. 699. pl. CV, figs. 4-6.

Not rare, but generally badly preserved.

308. PULVINULINA CONCENTRICA, Parker & Jones.

Pulvinulina concentrica, (Parker & Jones, MS.,) Brady, 1864, Trans. Linn. Soc., vol. XXIV, p. 470, pl. XLVIII, fig. 14.
Pulvinulina concentrica, Brady, 1884, Chall. Rep., vol. IX. p. 686, pl. CV, fig. 1, a, b, c.

Extremely rare. Only one small specimen found low down in the beds.

309. Pulvinulina punctulata, (d'Orbigny.)

Rotalia punctulata, d'Orbigny, 1826, Ann. Sci. Nat. vol. VII, p. 273, No. 25.
Pulvinulina punctulata, Brady, 1884, Chall. Rep. vol. IX, p. 685, pl. CIV, fig. 17, a, b, c.

Rare. A few damaged specimens found in a sample of Marl taken from about the middle of the beds (No. 5.)

310. Pulvinulina favus, Brady.

Pulvinulina favus, Brady, 1877, Geol. Mag. Dec. II, vol IV., p. 535, no figure.
Pulvinulina favus, Brady, 1884, Chall. Rep. vol. IX, p. 701, pl. CIV, figs. 12-16.

Rare. The examples found are small and the peripheral edge is not obtuse as in the specimens figured by Brady, but is provided with a thin keel. The areolation also is somewhat irregular. Most frequent in Gatherings 7 and 8.

(The specimens differ considerably from the Challenger types. The numerous recent specimens which we have seen are all keelless and with a rounded periphery, and the aperture is prominent and on the median line. In the Biarritz fossils there is always a sharp peripheral edge, sometimes a sharp keel. The aperture is always inconspicuous and situated on the inferior surface. The ornamentation is also more abundant and delicate in the fossils.)

311. Pulvinulina schreibersii, (d'Orbigny.)

Rotalina schreibersii, d'Orbigny, 1846, Foram. Foss. Vienne, p. 154, pl. VIII, figs. 4-6.
Pulvinulina schreibersii, Brady, 1884, Chall. Rep , p. 697, pl. CXV, fig. 1.

Not rare. The specimens noted are well grown and typical and were chiefly found in the upper beds. Though the species is probably present in the lowest beds, it does not attain its best development or growth until the very topmost layers of the clay.

312. Pulvinulina procera, Brady.

Pulvinulina procera, Brady, 1881, Quart. Journ. Micr. Soc., vol. XXI, N.S., p. 66, (no figure).
Pulvinulina procera, Brady, 1884, Chall. Rep., vol. IX, p. 698, pl. CV, fig. 7, a, b, c.

Very rare. Three small examples found in three separate Gatherings, 2-4-5, (1893.)

[313. CYCLOLOCULINA ANNULATA, Heron-Allen & Earland.]

[*Cycloloculina annulata*, Heron-Allen & Earland, 1908, &c., S.B. 1908, pp. 533, 536, Pl. XII. figs. 1-7.]

313A. PULVINULINA VERMICULATA, (d'Orbigny.)

Planorbulina vermiculata. d'Orbigny, 1826, Ann. Sci. Nat. vol. VII, p. 280, No. 3.
Pulvinulina vermiculata, Brady, 1884, Chall. Rep., vol. IX, p. 687, pl. CXV, fig. 2, a, b.

Extremely rare. The only specimen found (G. No. 3) is very small and regular in outline, being disc shaped. The longer segments are of equal diameter throughout, and at first sight the shell has the external appearance of *Spirillina vivipara*, Ehrbg., but a careful examination by transmitted light reveals its true character.

(The single specimen when remounted in balsam proved to be our Selsey genus and species *Cycloloculina annulata*, a very interesting find, although we have also found it in the Eocene of Paris since we recorded it from Selsey.)

314. PULVINULINA AURICULA, (Fichtel & Moll.)

Nautilus auricula, var. *a* Fichtel & Moll., 1803, Test. Micr. p. 108, pl. XX, figs. a, b, c.
Pulvinulina auricula, Brady, 1884, Chall. Rep. vol. IX, p. 688, pl. CVI, fig. 5, a, b, c.

Very rare and small. Only found in Gatherings, April, 1897.

314A. [PULVINULINA OBLONGA (Williamson).]

[*Nautilus auricula*, var. *β*, Fichtel & Moll, 1798, TM. p. 108, pl. XX. figs. d, e, f.
Rotalina oblonga, Williamson, 1858, RFGB. p. 51, pl. IV. figs. 98-100.
Pulvinulina oblonga, Brady, 1884, FC, p. 688, pl. CVI, fig. 4, a, b, c.]

[315. PULVINULINA ERINACEA, Karrer.]

315A. PULVINULINA OBLONGA, var. SCABRA, Brady.

Plate VIII, fig. 8.

Pulvinulina oblonga, var. *scabra*, Brady, 1884, Chall. Rep., vol. IX, p. 689, pl. CVI, fig. 8 a, b, c.

Not rare. Found almost exclusively in the upper portion of the Marl. On comparing my drawing with those of Brady, it

will be seen that the specimens from the Côte des Basques differ from the recent ones in having a sunken umbilicus in the centre of the inferior surface of the test, and also in not being so elongated. In these particulars my specimens resemble a species from Miocene strata described by Karrer under the name of *Pulvinulina erinacea**. Karrer's drawings show a rounded shell which is nearly circular in plan and which has a spinous superior surface with slightly depressed sutures. The inferior surface is smooth and shows seven segments in the final whorl. It seems to me to be quite possible that *P. erinacea* may be a weak starved form of Brady's variety, and consequently Karrer was the discoverer and first recorder of the form, and the name he gave it would have the priority, though undoubtedly Brady's description and recognition of its true position is the correct one.

(The specimens appear to be identical with Karrer's *P. erinacea* (K. 1868 M.F.K.B., p.187, pl. V, fig. 6.), a form which appears to have sufficient distinctive features to justify its being regarded as distinct from Brady's *P. oblonga* var. *scabra*.)

316. Pulvinulina hauerii, (d'Orbigny.)

Rotalina haueri, d'Orbigny, 1846, Foram. Foss. Vienne, p. 151 pl. VII, figs. 22-24.

Pulvinulina hauerii, Brady, 1884, Chall. Rep. vol. IX, p. 690. pl. CVI, figs. 6-7.

Frequent. Specimens typical but not large.

317. Pulvinulina hauerii, var. crassa, nov.

Plate VII, fig. 6.

This is a robust development of the type, and differs from it in the following particulars.

The test is rounded in contour, strongly built, the inferior surface conical, the superior nearly flat, the oral aperture is large and irregular and sometimes divided into two portions by a transverse partition, the part of the whorl near the oral aperture is marked with strong raised ridges or beads. The sutures on the inferior side of the shell are limbate. This variety is much larger than *P. hauerii*, and the shell wall is very thick. It is not frequent, and has only been found in Gatherings which are remarkable for the larger size of other species, so that its peculiar characteristics are undoubtedly due to a particularly favourable environment. Diameter of large specimen 1.75 mm., height, 1.35 mm.

* Sitz. d.k. Akad. d.w. math. naturw, Cl. LVIII, Bd 1,Abth. 1868.

(The most distinguishing feature of this variety as compared with the other Biarritz specimens is its abnormal size and corresponding increase in the development of markings. As Halkyard says that the only specimens were obtained in Gatherings remarkable for the large size of other species, it would appear to be merely a case of intensive development owing to favourable conditions of life.)

GENUS ROTALIA, Lamarck.

318. ROTALIA SOLDANII, d'Orbigny.

Rotalia (*Gyroidina*), *soldanii*, d'Orbigny, 1826, Ann. Sci. Nat., vol. VII, p. 278, No. 5.
Rotalia soldanii, Brady, 1884, Chall. Rep. vol. IX, p. 706, pl. CVII, figs. 6-7.

Frequent. Found in all Gatherings.

319. ROTALIA UMBILICATA, d'Orbigny.

Rotalia umbilicata, d'Orbigny, 1840, Mém. Soc. Géol. France. ser. I, vol. IV, p. 32, pl. III, figs. 4-6.
Rotalia soldanii, var. *nitida*. Chapman, 1897. Journ. Roy. Micr. Soc., 1898, p. 9, pl. II, fig. 2, a-c.

Rare. My specimens seem to be identical with *Rotalina nitida*, Reuss, if Chapman's figure of that species is drawn from a typical specimen. I have not been able to see Reuss' original figure, but there is no doubt that d'Orbigny's figure of the chalk species and Chapman's of his specimens from the Folkestone Gault resemble each other closely, and both might have been drawn from specimens in the collections from the Côte des Basques. In this case d'Orbigny's specific name would have the preference, he having published his description in 1840.

Carpenter and Brady referred this form to *R. soldanii*, d'Orb., and were certainly correct from their point of view, for it must not be forgotten that they were regarding the question somewhat broadly, and with a laudable desire to prevent undue multiplication of specific names. When, however, one finds in a series of Gatherings like the present the typical *R. soldanii* and also its variety *R. umbilicata* unconnected by intermediate forms and easily distinguishable one from the other, it is convenient to retain their distinctive names.

(The specimens agree very well with d'Orbigny's original figures (d'O. 1840, C.B.P. p. 32, pl. III, figs. 4-6.) The original Reuss figures of *Rotalina nitida* are too small to be serviceable

for identification, but the description shows the form to be a variety of *R. soldanii*, and probably identical with d'Orbigny's species *R. umbilicata*. Halkyard's separation of *R. umbilicata* in the Biarritz material is more than justified owing to the very strong local development of the typical *R. soldanii*.)

320. Rotalia calcar, (d'Orbigny).

Calcarina calcar, d'Orbigny, 1826, Ann. Sci. Nat. vol. VII, p. 276, No. 1.
Rotalia calcar, Brady, 1884, Chall. Rep., vol. IX, p. 709. pl. CVIII, fig. 3; and fig. 4?

Frequent. Examples small as a rule; the larger ones lose a good deal of the clear feature of the species, the exterior margin of the segments becoming curved instead of pointed.

(The species show gradual transition from the long spined *R. calcar* to spineless forms very near *R. venusta*, Brady.)

321. [Nonionina kochi, (Hantken.)]

321a. Rotalia pulchella, (d'Orbigny).

Calcarina pulchella, d'Orbigny, 1839, in De la Sagra's Hist. Phisiq. etc., de Cuba, pt. "Foraminiféres," p. 80. pl. V, figs .16-18.
Rotalia pulchella, Brady, 1884, Chall. Rep. vol. IX, p. 710, pl. CXV, fig. 8, a, b.

Rare. The few specimens found are small and weak, and resemble d'Orbigny's rather than Brady's figure.

(A close examination of Halkyard's specimens makes it impossible to retain the species under his determination. They cannot be compared either with d'Orbigny's original Cuba figure, or with the much more familiar Malay type assigned by Brady to d'Orbigny's species although very dissimilar from d'Orbigny's figure. Halkyard's specimens instead of being rotaliform in structure, as in the d'Orbigny-Brady types, are involute, and must therefore be assigned either to the genus *Nonionina*, or to its globigerine isomorph *Pullenia*. Apart from this generic distinction the arrangement of the spines is quite different to the d'Orbigny-Brady types, in both of which the number of spines is limited to three and they are solid and set at equally divergent angles from the centre of the test. In the Biarritz specimens, which are unfortunately few in number and mostly damaged, the spines are tubular and their number

varies from two, set on successive chambers of a perfect but immature shell, to four set on successive chambers of a large but broken test, which probably had a fifth spine on its missing terminal chamber. Moreover the spines, instead of being radially symmetrical as in the d'Orbigny-Brady types, point forward from the margin, at a tangent to the spiral of growth.

Halkyard's specimens appear to be very similar if not identical with the obscure form described and figured by Hantken (1875, Mitt. Jahr. k. ung. geol. Anst. vol. IV, pt. I, p. 79, pl. XVI, fig. 1) from the "*Clavulina Szaboi-Schichten*" under the name of *Siderolina kochi*. His description is as follows:— "The shell is composed of five pouch-shaped chambers, which terminate in front in a tube-shaped continuation, at the end of which is placed the aperture. Both sides are nearly similar. (0.5 mm)."

Hantken's figures represent a five-chambered involute spiral test. The earliest visible chamber is furnished with a stout projecting spine, and the four later chambers have a blunted apical projection from their forward extremity.

Liebus in 1911 (*Liebus, Foram. mitteleocänen Mergel v. Norddalmatien*, Sitzb. k. Akad. Wiss. Wien. vol. CXX, pt. I, (1911), p. 78, pl. II, figs. 9-10, figures under the name of *Pullenia kochi* (Hantken) what appears to be the same form. He very properly removes it from *Siderolina*, and comparing its structure with *Globigerina digitata*, Brady transfers the species to *Pullenia*. Liebus writes as follows:—

"Since the first description of this form by Hantken, (l.c., p. 79, pl. XVI, fig. 1), it has never been properly treated. Hantken himself gives no further explanation of the inner construction of the test. In the material examined, small fragments as well as perfect examples were fairly frequent. On the surface for the most part, only four arched chambers are to be distinguished, separated by deep sutures. Of these at least the youngest posseses stalk-like projections, which are hollow inside. There is no clear distinction between spiral and umbilical. In some instances the umbilical side is somewhat deepened. The superstructure is clear, smooth and polished. It shows, roughly speaking, a rotaliform plan, the chambers are in two convolutions, almost surrounding each other. Each younger chamber embraces the one in front, (i.e., each later chamber embraces its predecessor. H-A & E.) so that they use this outer wall as basis, and only form a new wall at the free portions. The separating walls of the chambers (they are only visible in the youngest portion of the test) are regularly marked with little channels.

"The little stalk-like projections from the chambers are, in the fully grown specimens, broken off at the commencement. Only a few young examples possess these projections of a fairly even length. I could not determine the position of the aperture with any certainty, in any of the examples.

"The name *Siderolina* I cannot hold correct. *Siderolina* should be identical with *Siderolites* (as *Nummulina* and *Nummulites*), but *Siderolina* (*S. kochi* (Hantken) understood. H-A & E.) is something quite different. The foregoing form belongs rather to *Pullenia*, or in the neighbourhood of the almost planospiral compressed *Globigerinæ*, whose chambers are arranged similarly to *G. digitata*."

Liebus figures the species both as an opaque object and in section and his drawings show a thick-walled finely perforate involute test with five chambers visible externally. The two final chambers extend forward at a tangent, and terminate in a large tubular opening. There is no suggestion of a spinous termination but the extensions are evidently broken. If the tubes originally terminated in a perforated spine as in the Biarritz specimens, they must have been enormously prolonged. One other chamber shows a similar perforate process on a minute scale, but the first and third chambers have an unbroken and symmetrical surface.

We are not satisfied with the allocation of the species to *Pullenia*. Its affinities are undoubtedly obscure, but the texture of the shell-wall appears to us to have little in common with *Pullenia*, and nothing but the external form is comparable with *Globigerina digitata* Brady, which has a characteristically globigerine wall. The texture of the wall in the Biarritz specimens strongly suggests *Nonionina*, although the presence of the perforate spines is quite alien to that genus. This feature indeed may render it necessary to institute a new genus for the specimens, whenever a further supply of material renders additional investigations into their structure possible. It is possible that the species may be found to be allied to the somewhat similar, but more minute organism described by Schacko under the name *Siderolina cenomana*. * For the present we prefer to record the Biarritz specimens as *Nonionina kochi* (Hantken), and to supplement the previously published remarks of Hantken and Liebus with the following note:—

Test free, involute, consisting of two or more convolutions of chambers rapidly increasing in size, armed in the later cham-

* Schacko. Foram. aus d. Cenomankreide von Moltzow i. Meckl.-Arch. d. Ver. d. Freunde d. Naturgesch, i. Meckl. vol. L. 1896, p. 166, figs. 3-5. *Vide* also:—*Siderolina cenomana*, Schacko, in Egger, 1899 Foram. Kreidem. d. Oberbay. Alpen. Abh. k. bayer. Ak. Wiss. Cl. II. vol. XXI. pt. 1, p. 174, pl. XXI, fig. 42.

bers with a stout acutely pointed spine attached to the terminal edge of the successive chambers. The spine is perforated by a median canal broad at the base where it communicates with the interior of the chamber and tapering to a very minute tube opening at the extremity of the spine. Umbilicus somewhat depressed as also are the sutures, chambers slightly inflated. The growth of the spines does not apparently begin until a complete whorl of chambers has been formed. Aperture very obscure, apparently typically nonionine. (All the specimens except very immature ones are broken in the final chambers.) The surface of the chambers finely perforate, somewhat rough. Only the chambers of the final convolution visible.

Breadth: .4—4.5 mm., Diameter: .25—.35 mm. without spines. Spines average .2 mm. in length, .075 mm. at base.

322. ROTALIA PAPILLOSA, var. COMPRESSIUSCULA, Brady.

Rotalia papillosa, var. *compressiuscula*, Brady, 1884, Chall. Rep., vol. IX, p. 708, pl. CVII, fig. 1, a, b, c.; pl. CVIII, fig. 1, a, b, c.

Very rare. My specimens resemble the latter drawing of Brady's with the difference that the sutures on the inferior surface are bent at an angle of about half their length, and do not take the slightly curved direction from the centre to the periphery of the test as shown in the above figures.

(The specimens are far from typical.)

FAMILY NUMMULINIDÆ.

SUB-FAMILY POLYSTOMELLINÆ.

GENUS NONIONINA, d'Orbigny.

323. NONIONINA DEPRESSULA, (Walker & Jacob.)

Nautilus depressulus, Walker & Jacob, 1798. Adam's Essays, Kannmacher's Ed., p. 641, pl. XIV, fig. 33.
Nonionina depressula, Brady, 1884, Chall. Rep. vol. IX p. 725, pl. CIX, figs. 6-7.

Rare. The specimens are also of a weak form. The shell is very thin, and the chambers are much inflated and few in number, only about six making up the last whorl. The umbilicus of the test is depressed and partially filled up with granular shell-matter.

324. Nonionina stelligera, d'Orbigny.

Nonionina stelligera, d'Orbigny, 1839, Foram. Iles Canaries. p. 128, pl. III, fig. 12.
Nonionina stelligera, Brady, 1884, Chall. Rep. vol. IX, p. 728, pl. CIX, figs. 3-5.

Extremely rare. Only one small specimen found in all the washings examined.

325. Nonionina umbilicatula, (Montagu.)

Nautilus umbilicatulus, Montagu, 1803, Test. Brit. p. 191; Suppl. (1808), p. 78, pl. XVIII, fig. 1.
Nonionina umbilicatula, Brady, 1884, Chall. Rep. vol. IX, p. 726, pl. CIX, figs. 8-9.

This species is not rare in my collections, and the examples noted are well-grown and typical.

326. Nonionina scapha, (Fichtel & Moll.)

Nautilus scapha, Fichtel & Moll. 1803. Test. Micr., p. 105, pl. XIX, figs. d-f.
Nonionina scapha, Brady, 1884, Chall. Rep., vol. IX, p. 730, pl. CIX, figs. 14, 15; and 16?

Rather rare. Occurs only in the lower half of the Marl beds.

(Many of the specimens should, in our opinion, be referred to *N. turgida*. Will.)

326a. [Nonionina boueana, d'Orbigny.]

[*Nonionina boueana*, d'Orbigny, 1846, FFV. p. 108, pl. V. figs. 11, 12.
Nonionina boueana, Brady, 1884, Chall. Rep. p. 729, pl. CIX, figs. 12, 13.]

Genus Polystomella, Lamarck.

327. Polystomella subnodosa. (Münster.)

Robulina subnodosa, Münster, 1838, (*fide* Roëmer). Neues Jahrb. für Min., etc., p. 391, pl. III, fig. 61.
Polystomella subnodosa, Brady, 1884, Chall. Rep., vol IX, p. 734, pl. CX, fig. 1, a, b.

Very rare and found only in the lower beds. The specimens are rather small and the septal pores are very indistinct.

SUB-FAMILY NUMMULITINÆ.

GENUS AMPHISTEGINA, d'Orbigny.

328. AMPHISTEGINA LESSONII, d'Orbigny.

Pl. VII, fig. 7.

Amphistegina lessonii, d'Orbigny, 1826, Ann. Sci. Nat. vol. VII, p. 304, No. 3, pl. XVII, figs. 1-4.
Amphistegina lessonii, Brady, 1884, Chall. Rep. vol. IX, p. 740, pl. CXI, figs. 1-7.

Rather rare. The specimens are all of the thick very inæquilateral type, and on the inferior surface the whole of the segments are generally visible.

GENUS OPERCULINA, d'Orbigny.

329. OPERCULINA COMPLANATA, (Defrance).

Lenticulites complanata, Defrance, 1822, Dict. Sci. Nat., vol. XXV, p. 453.
Operculina complanata, Brady, 1884, Chall. Rep. vol. IX, p. 743 pl. CXII, figs. 3-5-8.

329A. [OPERCULINA COMPLANATA, var. GRANULOSA, Leymerie.]

[*Operculina granulosa*, Leymerie, 1846, Mém. Soc. Géol., France, ser. 2, vol. I (1884), p. 359, pl. XIII, fig. 12 a, b, c.
Operculina complanata var. *granulosa*. Brady, 1884, Chall. Rep. vol. IX, p. 743, pl. CXII, figs. 6, 7, 9, 10.]

Frequent and fairly well distributed. Between the typical smooth form and the beaded variety *granulosa* there is such a graduated series that I have included all specimens found under the type, though well-marked examples of the ornamented variety occur fairly numerous.

(All the specimens, both of the species and of its variety *granulosa* are of the thin complanate type.)

NUMMULITES.

(Halkyard has identified and described a large number of *Nummulites* and *Orbitoides* from the Biarritz material, both in isolated species and in megalo-and microspheric pairs. It is clear from the correspondence in our hands that he took great pains to obtain verification of his identities from several authorit-

ative workers on the group. We cannot do more than indicate some of the principal papers which have been published upon the Biarritz species of these somewhat bewildering and highly specialized genera.

It need not be pointed out that the Bibliography of the Nummulites is vast, and that in a very large number of the papers and books, these beds are referred to more or less extensively. We propose only to cite some of the strictly localized papers. For the general literature of the subject up to 1847 see A. Boué's paper "Ueber die Nummuliten Ablagerungen," (Haidinger's Ber. u. d. Mitth. von. Freunden des Naturwiss. in Wien. vol. III, 1848, pp. 446-470); up to 1888 Sherborn's "Bibliography"; and for later papers the works of Boussac, Douvillé, and van den Broeck.)

1844. Leymerie, A. F. G. A. Mémoire sur le Terrain à Nummulites (épicrétacé) des Corbières, etc. Mém. Soc. Géol. France, Ser. 2, Vol. I, 1844 (1846), pp. 337-375. Pls. XII-XVII.

1845. Leymerie, A. F. G. A. Résumé d'un Mémoire sur le Terrain à Nummulites (épicrétacé) des Corbières, etc. Bull. Soc. Géol., France. Ser. 2. Vol. II, 1845, (44), pp. 11-37.

1846. d'Archiac, E. J. A. Description des Fossiles receuillis par M. Thorent dans les couches à Nummulites des environs de Bayonne. Mém. Soc. Géol. France. Ser. 2. vol. II, 1846, pp. 189-217, pl. V.

1847. ——Les Fossiles des couches à Nummulites des environs de Bayonne et de Dax. Bull. Soc. Géol., France. Ser. 2, vol. IV, 1847, pp. 1006-1013.

1848. ——Descriptions des Fossiles du groupe Nummulitique receuillis . . . . aux environs de Bayonne et de Dax. Mém. Soc. Géol., France. Ser. 2, Vol. III, 1848. pp. 397-456. Pls. VIII-XIII.

1879. de la Harpe, P. Coup d'Œil général sur les Nummulites de Biarritz. Bull. Soc. Borda à Dax, Ann. 4 (1879), pp. 59-63.
——Description des Nummulites appartenant à la Zone supérieure des Falaises de Biarritz.
Ibid. pp. 137-156, pl. I.

1880. ——Description des Nummulites appartenant à la Zone moyenne des Falaises de Biarritz.
Ibid. Ann. 5, 1880, pp. 65-71, figs.

1881. de la Harpe, P.—Description des Nummulites appartenant à la Zone inférieure des Falaises de Biarritz, des environs de la Villa Bruce jusqu' à Handia.
Ibid. Ann. 6, 1881, pp. 27-40.
——Description des Nummulites des Falaises de Biarritz Additions et Corrections. Ibid. pp. 229-243.

1903. Douvillé, H.—Sur le terrain Nummulitique à Biarritz et dans les Alpes.
Bull. Soc. Géol. France, Ser. IV, Vol. II, 1903, pp. 149-154.

1905. Douvillé, H.—Le terrain Nummulitique du Bassin de l'Adour.
Bull. Soc. Géol. France. Ser. 4, vol. V, 1905, pp. 9-55.
Prever. P.L.-Terreni Nummulitici di Gassino e di Biarritz. Att. Acc. R. d. Sci. Torino Ann. 1905-6, vol. XLI, (pp. 17.)

1908. Boussac, J.—Note sur la succession des Faunes Nummulitiques à Biarritz.
Bull. Soc. Géol. France, Ser. 4, Vol. VIII, 1908, pp. 237-255. H-A. & E.)

Genus Nummulites, Lamarck.

Before passing on to speak of the particular species of this genus found in the Blue Marl it will not be out of place to say a few words on the present state of our knowledge as regards the dimorphism of the group. It has long been recognised that there occurred in all Nummulitic deposits certain "couples" of Nummulites, for example where *N. variolaria*, Sowerby, is found it is always associated with *N. heberti*, d'Archiac, though for reasons stated below the latter form was not always recognised. The only external difference between these two forms (it must be borne in mind that these two forms are only taken as examples of many other couples and to make my statements more clear) is that the latter is generally superior in dimensions to the former. This of itself would not attract much remark as of course the size of a given species of *Nummulites* depends much upon its age, and is consequently very variable. A further examination of the two forms is therefore necessary. On splitting the shells in the spiral plane it will be found that the central or primordial chamber of *N. variolaria* is large and spherical whilst that of *N. heberti* is extremely minute and in fact hardly distinguishable. The two forms are known respectively as the "megalospheric" or "A" form and the "microspheric" or "B" form. A similar dimorphism occurs in other Orders and Genera of the Foraminifera. There is no doubt that the

"couples" of Nummulites are really referable to one species. Now for the "raison d'etre" of these two forms. J. J. Lister* has made most exhaustive researches into the mode of reproduction of *Polystomella crispa*, (Linné.) and the results of his observations he sums up as follows:—"We may conclude then, that the microspheric and megalospheric forms of the Foraminifera represent alternating or recurring generations in a life-cycle. While the megalospheric generation arises asexually either from a microspheric or a megalospheric parent, it is probable that the microspheric generation arises sexually, i.e., by the conjugation of two similar zoöspores." Here it may be said that the megalospheric form in Nummulites is always very much more numerous than form B.

A revision of the nomenclature of the *Nummulites* is now recognised as necessary, and M. Van den Broeck† seq put forward two schemes both of which have something in their favour. The first consists in retaining the specific name of Form A, and considering that the normal type on account of its numerical superiority over Form B. Though both convenient and securing a biological unity of the group, this scheme violates the rules of zoological nomenclature as regards the priority of specific names; in some cases the megalospheric form having been first discovered, and in others the microspheric having been the first to receive a specific name. The second scheme consists in respecting the law of priority of name, but in this case there is the difficulty of the specific name retained being sometimes that of the microspheric, and at others that of the megalospheric form. Personally I am in favour of the first of Van den Broeck's proposals, as there have already been exceptions made to the priority rule in favour of several other groups of Animals, and I do not see why the same advantages should not be accorded the Foraminifera, particularly as such a course would settle the question under consideration, in fact, without such a solution I can see no way at all out of the difficulty. In my record of the Biarritz Nummulites I propose to treat the "couples" under one heading, giving both specific names, but it will be quite clear that the two forms are referable to a single species, whatever may be the specific name eventually adopted.

Below I give examples of the two schemes proposed by Van den Broeck, and as the same forms are given in both examples, it will enable an opinion to be formed of their respective merits.

* A treatise on Zoology, edited by E. Ray-Lankester, p. 77.

† "Comment faut il nommer les Nummulites en tenant compte de leur Dimorphism." Bulletin Soc. Belge de Géologie, Tome X. 1896, pp. 50-62.

First Scheme.

NUMMULITES ELEGANS, Sowerby, (1829.)
NUMMULITES ELEGANS *(B) planulata*, Lamarck, 1804.

Second Scheme.

NUMMULITES (*B*) *planulata*, Lamarck, 1804.
NUMMULITES, PLANULATA, Lamarck, (*A*) *elegans*. Sowerby, 1829.

The species of *Nummulites* in which the two forms have been recognised may up to the present amount to some twenty or twenty-five.

In the soft Marls of the Côte des Basques, the genus is comparatively rare, and the specimens found are not in sufficient number to allow of any estimate being made as to the relative proportions of the forms A and B. Nummulites are, however, very plentiful in the sands overlying the Marls and also appear again in considerable quantities in the hard limestones at the base of the Marls. These facts seem to show that a muddy sea bottom does not provide a suitable habitat for the genus, or else that soft Marl, which is liable to extremes of dryness and moisture, is not conducive to the preservation of its fossil remains.

De la Harpe records six Nummulites from the Côte des Basques of which four fall into two "couples" and are bracketed as such.

{ *Nummulites contorta*, Deshayes.
{ *Nummulites striata*, d'Orbigny.

{ *Nummulites guettardi*, d'Archiac.
{ *Nummulites biarritzensis*, d'Archiac.

Nummulites variolaria, Sowerby.

Nummulites lucasana, Defrance.

Of the above I have only found four forms, but I have been fortunate enough to add others to the list.

330. 2—NUMMULITES IRREGULARIS, Deshayes.

330A. 1—NUMMULITES SUB-IRREGULARIS, de la Harpe.

Nummulites irregularis, Deshayes, 1838, Mém. Soc Géol. France, [1], vol. III, p. 67, pl. V, figs. 15-16.
N. irregularis, de la Harpe, 1883, Mém. Soc. paleont. Suisse, vol. X, p. 154, pl. IV, figs. 16-34; and pl. V, figs. 1-2.
1—*N. sub-irregularis*, de la Harpe, 1883, Mém. Soc. paleont, Suisse, vol. X, p. 158, pl. V, 3-14.

Of the very few specimens I have found, the megalospheric form, *N. sub-irregularis*, is larger than the microspheric one, *N. irregularis*, but this seeming anomaly is easily accounted for as my specimens of the latter have the appearance of being all young tests. The spire has very few convolutions, the shell wall is very thin, and the irregularity of growth is not so marked as it would be in mature specimens. Another point to be noticed is that the two forms have been found in about equal quantities, but as both are rare this must not be taken as an ordinary, but rather as a very extraordinary state of affairs. Any conclusion as to the proportional rarity of the two forms founded on my collections would undoubtedly be a false one, the material being much too limited in quantity to allow of any satisfactory results being arrived at. This applies equally to all the *Nummulites* which I have found in these Marls.

331. Nummulites variolaria. (Lamarck.)

331a. Nummulites heberti, d'Archiac.

Lenticulites variolaria, Lamarck, 1804, Ann. Mus., vol. V, p. 187, No. 2.

Num. variolaria, De la Harpe, 1883, Mém. Soc. Paléont. Suisse vol. X. p. 177, pl. VII, figs. 24-32.

Num. heberti, d'Archiac & Haime, 1853, Descrip. Anim. groupe Nummulitique Inde. vol. I, p. 147, pl. IX, figs. 14-15.

Of these two forms the megalospheric *N. variolaria* is smaller and more plentiful than its companion. It is also the commonest Nummulite in my collections and generally very well preserved.

332. Nummulites guettardi d'Archiac & Haime.

332a. Nummulites biaritzensis, d'Archiac & Haime.

Num. guettardi, d'Archiac & Haime, 1853, Descr. Anim. groupe Nummulitique Inde, vol. I, p. 130, pl. VII, figs. 18-19.

Num. biaritzensis, d'Archiac & Haime, 1853, Descr. Anim. groupe Nummulitique Inde, vol. I, p. 131, pl. VII, figs. 4-5.

N. guettardi (Form A) is much smaller and far outnumbers *N. biaritzensis*, and my specimens are in more favourable state of preservation for examining the interior structure, being often free from any infiltration of foreign matter whilst the few examples found of *N. biaritzensis* are hard, and very little else than blocks of crystalline limestone, so that it is difficult to make out their true character.

333. NUMMULITES HEERI, de la Harpe.

Nummulites heeri, de la Harpe, 1883, Mém. Soc. paléont Suisse, vol. X, p. 152, pl. IV, figs. 9-15.

This species is rare in my collections, and the microspheric form *N. murchisoni*, (Brünner), has not been noticed by me.

334. NUMMULITES CONTORTA, Deshayes.

Nummulites contortus, Deshayes, 1848, In Ladonette's Hist. des. Hautes-Alpes, ed. 3, p. 487, pl. XIII, figs. 7-9.
N. contorta, D'Archiac & Haime, 1853, Descr. Anim. groupe Nummulitique Inde, vol. I, p. 136, pl. VIII, fig. 8.

Microspheric very rare. Form A, *N. Striata*, (d'Orb.), has not been found.

335. NUMMULITES FICHTELI, Michelotti.

Nummulites fichteli, Michelotti, 1841, Mém. Soc. Ital. Sci., vol. XXII, p. 296, pl. III, fig. 7.

Very rare, only four or five specimens found. This is a megalospheric form, and its microspheric companion is *N. intermedia*, d'Archiac, which, though undoubtedly present in the Côte des Basques deposits has not been discovered by me.

336. NUMMULITES BOUCHERI, de la Harpe.

Nummulites boucheri, de la Harpe, 1879, Bull. Soc. Borda à Dax, vol. IV, p. 146, pls. I, IV, figs. 1-10.
N. boucheri, de la Harpe, 1883, Mém. Soc. paléont, Suisse. vol. X, p. 179, pl. VII, figs. 33-59.

This is a megalospheric form, and is rare in the Marls. De la Harpe figures two varieties which he names respectively *tenuispira* and *incrassata*. The form B of the species is unknown to me.

337. NUMMULITES CURVISPIRA, Meneghini.

Nummulina curvispira, Savi & Meneghini, 1851, Consid. Geol. Toscana, p. 137, no figure.
Nummulites curvispira, D'Archiac & Haime, 1853, Descr. Anim. groupe Nummulitique Inde, vol. I, p. 127, pl. VI, fig. 15.

This handsome species is not uncommon in my collections and both the megalospheric and the microspheric forms have been found. The latter however is much rarer than the former.

338. Nummulites (Assilina) mammilata, (d'Archiac.)

338a. Nummulites (Assilina) exponens, Sowerby.

Numm. (*Assil.*) *mammilata*, d'Archiac, 1853, Deser., Anim., groupe Nummulitique Inde, vol. I, p. 154, pl. XI, figs. 6-8

Nummulina mammilata, d'Archiac, 1847, Bull. Soc. Géol., France [2], vol. IV, p. 1010.

Nummularia exponens, Sowerby, 1834, (1840.) Trans. Geol. Soc. London, [2], vol. V, p. 719, pl. LXI, fig. 14.

Numm. exponens, D'Archiac & Haime, 1853, Deser. Anim. groupe Nummulitique Inde, vol. I, p. 148, pl. X, figs. 1-10.

N. mammilata which is the megalospheric form is very much more common than *N. exponens* the microspheric form. Of about twenty-five specimens examined only one was found with a microsphere. This specimen differs somewhat from the type in that the spire is rather more open than usual and the chambers are broader.

SUB-FAMILY CYCLOCLYPEINÆ.

Genus Orbitoides, d'Orbigny

339. Orbitoides papyracea, (Boubée.)

Nummulites papyracea, Boubée, 1832, Bull. Soc. Géol. France, vol. II, p. 445, no figure.

Orbitoides (*Discocyclina*) *papyracea*, Gümbel, 1868 (1870), Abh. m.-ph. Cl. k.-bayer, Ak. Wiss. vol. X, p. 690, pl. III, figs. 3-12, figs. 19-29.

Very common, particularly in the hard layers of the lower part of the Marls where seams several inches thick occur, formed almost entirely of this species with an admixture of different species of *Nummulites*. In the softer beds of the Marl it is rarer, but still the commoner form of the genus.

340. Orbitoides (Discocyclina) aspera, Gümbel.

Orbitoides (*Discocyclina*) *aspera*, Gümbel, 1868 (1870), Abh. m. ph. Cl. K. bayer, Ak. Wiss, vol. X, p. 698, pl. III, figs. 13-14; and figs. 32-34.

Rare in upper soft Marls, more frequent in lower and harder beds.

341. ORBITOIDES (DISCOCYCLINA) DISPANSA, (Sowerby.)

Lycophris dispansus, Sowerby, 1837, (1840), Trans. Geol. Soc. Lond., [2], vol. V, p. 327, p. 718, pl. XXIV, fig. 16.
Orbitoides (Discocyclina) dispansa, Gümbel, 1868, (1870), Abh. m.-ph. Cl. k-bayer, Ak. Wiss. X, p. 701, pl. III, figs. 40-47.

Rare on the Côte des Basques. In the bed of the Chabiague Brook, which is outside the limits from which the collections now under description were taken, there are horizontal layers of indurated Marls containing large quantities of *Orbitoides dispansa*. These layers appear to be the lowest of the Blue Marls. At any rate they are the lowest in sight.

342. ORBITOIDES (ASTEROCYCLINA) STELLATA, (d'Archiac.)

Calcarina stellata, d'Archiac, 1846, Mém. Soc. Géol. France, [2], vol. II, p. 199, pl. VII, fig. 1.
Orbitoides (Asterocyclina) stellata, Gümbel, 1868 (1870), Abh. m.-ph. Cl. k.-bayer, Ak. Wiss., vol. X, p. 713, pl. II, fig. 115; and pl. IV, figs. 4-7.

Generally distributed but rather rare.

343. ORBITOIDES (ASTEROCYCLINA) STELLA, Gümbel.

Orbitoides (Asterocyclina.) stella, Gümbel, 1868 (1870), Abh., m.-ph. Cl. k.-bayer. Ak. Wiss vol. X, p. 716, pl. II, fig. 117; and pl. IV, figs. 8-10, 19.

Rare, and only found in two Gatherings.

344. ORBITOIDES (AKTINOCYCLINA) RADIANS (d'Archiac).

Orbitolites radians, d'Archiac, 1848, Mém. Soc. Géol., France. [2], vol. III, p. 405, pl. VIII, fig. 15.
Orbitoides (Aktinocyclina) radians, Gümbel, 1868 (1870), Abh. m. ph., Cl. k.-bayer, Ak. Wiss. vol. X, p. 707, pl. II, fig. 116; and pl. IV, figs. 11-15.

Very rare. In the whole of my collections only one specimen was found, that occurring in No. 3a Gathering of No. 2 series.

345. ORBITOIDES (AKTINOCYCLINA) TENUICOSTATA, Gümbel.

Orbitoides (Aktinocyclina) tenuicostata, Gümbel, 1868, (1870), Abh. m.ph. Cl. k.-bayer. Ak. Wiss., vol. X, pl. II, fig. 114; and pl. IV, fig. 35.

Rare in sandy pockets in the softer Marls.

APPENDIX A.

Foraminifera mentioned by the Count de Bouillé in his "Paléontologie de Biarritz" and localities where found.

	Remarks.
Chambre d'Amour.	
Nummulites vasca, Joly and Leymerie.	Espèce répandue, d' après d'Archiac, depuis la Chambre d' Amour jusqu' à l'Est du Phare.
Operculina ammonea, Leymerie.	var. in d'Archiac.
Nummulites intermedia, d'Archiac.	Espèce répandue depuis la Chambre d' Amour jusqu' au Campost d' Etienne ou Tres pots.
Phare de Biarritz.	
Operculina ammonea, Leymerie.	var. in d'Archiac.
Lou Cachaou.	
Operculina ammonea, Leymerie.	
Orbitolites papyracea, d'Archiac.	Mistake of genus. Ought to be "Orbitoides," not "Orbitolites."
,, Fortsii d'Archiac.	
,, sella, d'Archiac.	
,, stellata, d'Archiac.	
Villa Bruce (Bed at 400 metres N. of villa).	
Operculina ammonea, Leymerie.	
,, Boissyi d'Archiac.	
Orbitolites radians, d'Archiac.	Ought to be "Orbitoides," not "Orbitolites."
,, stellata, d'Archiac.	
,, Fortsii and var. d'Archiac.	
,, papyracea, d'Archiac.	
,, sella, d'Archiac.	
Nummulites planulata, Lamarck.	
,, Brongniarti, d'Archiac	
,, spira, de Roissy.	
La Gourépe.	
Nummulites Dufrenoyi, d'Archiac.	
,, variolaria, Sowerby.	
,, Biaritzensis. d'Archiac.	

Num. Orbignyi, Galeoti sp.
,, Wemmelensis, de la Harpe & Van den Broeck.
,, ,, var. plicata ,, ,,
,, ,, var. granulata ,, ,,
,, ,, var. Prestwichi ,, ,,
,, planulata, Lamk.
,, ,, ,, var. incrassata, de la Harpe.
,, elegans, Sowerby.
,, ,, ,, var. depressa, de la Harpe.
,, vasca, Joly & Leymerie.
,, ,, ,, ,, var. incrassata, de la H.
,, ,, ,, ,, ,, tenuispira ,,
,, Boucheri, de la Harpe.
,, ,, ,, var. tenuispira ,,
,, ,, ,, var. incrassata ,,
,, subpulchella, de la Harpe.

Couples. a, with microsphere. b, with megalosphere.

N. complanata, Lam.	N. Tchihatcheffi, d'Arch. .....
,, perforata, d'Orb.	,, Lucasana, Defr. .....
,, intermedia, d'Arch.	,, Fichteli, Michel. .....
,, contorta, Desh.	,, striata, d'Orb. .....
,, Biaritzensis, d'Arch.	,, Guettardi, d'Arch. .....
,, laevigata, Lam.	,, Lamarcki, d'Arch. .....
,, planulata, d'Orb.	,, elegans, Sow. .....
,, Heberti, d'Arch.	,, variolaria, Sow. .....
Assilina exponens, Sow.	Ass. mammillata, d'Arch. .....
,, spira, de Roissy	,, subspira, de la Harpe .....
,, granulosa, d'Arch.	,, Leymeriei, d' Arch. .....
N. Orbignyi, Galeoti	,, Wemmelensis, de la Harpe and Van den Broeck
,, Biricensis, de la H.	,, Budensis, Hantken. .....
,, Bouillei, de la H.	,, Tournoueri, de la H. .....
Num. Murchisoni, Brun.	N. Heeri, de la H. .....
,, irregularis, Desh.	,, subirregularis, de la H. ...

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PLATE I.

FIG. 1. —Pentellina lævis, sp. nov., x 36.
a, *b*.—Lateral aspects.
c.—Oral aspect.

FIG. 2. —Hauerina fragillissima, (Brady), x 73. Transverse section.

FIG. 3. —Aschemonella catenata, (Norman), x 31.

FIG. 4, 5.—Reophax plana, sp. nov., x 21.
4*a*.—Lateral aspect.
4*b*.—Oral aspect.
5.—Lateral aspect.

FIG. 6. —Nouria polymorphinoides, Heron-Allen & Earland, x 18.
a, *b*.—Lateral aspects.
c.—Peripheral aspect.

FIG. 7. —Nouria polymorphinoides, Heron-Allen & Earland, x 21.
a.—Lateral aspect.
b.—Peripheral aspect.

FIG. 8. —Iridia diaphana, Heron-Allen & Earland, [?] x 25.
a.—Lateral aspect.
b.—Oral aspect.

FIG. 9. —Haplophragmium tumidum, sp. nov., x 21.
a.—Lateral aspect.
b.—Peripheral aspect.

FIG. 10. —Ammodiscus milioloides, (Jones, Parker & Kirkby), x 36.
a, *b*.—Lateral aspects.
c.—Peripheral aspects.

PLATE II.

FIGS. 1-4. —Carpenteria proteiformis, Goës, x 25.
FIG. 5. —Carpenteria proteiformis, Goës.
Vertical section of two chambers of a linear series, x 25.

FIG. 6. —Textularia biarritzensis, sp. nov., x 63.
a.—Peripheral aspect.
b.—Lateral aspect.
c.—Oral aspect.

FIGS. 7-9. —Gaudryina rugosa, var. difformis, nov., x 31.
a, *b*.—Lateral aspects.
c.—Oral aspect.
8.—Oral aspect of another specimen, x 44.
9.—Transverse section of aboral end of test. x 44.

FIGS. 10-13.—Bigenerina capreolus, (d'Orbigny).
10*a*.—Lateral aspect, x 36.
10*b*.—Oral aspect, x 36.
11*a*.—Lateral aspect, x 31.
11*b*.—Oral aspect, x 31.
12.—Vertical section of test, x 36.
13.—Lateral aspect, x 31.

PLATE III

FIGS. 1-3.—Clavulina gaudryinoides, Fornasini, x 25.
1*a*, 2*b*.—Peripheral aspects.
1*b*, 2*a*.—Lateral aspects.
1*c*, 2*c*.—Oral aspect.
3.—Transverse section of aboral portion of test.

FIGS. 4-6.—Clavulina angularis, d'Orbigny, x 22.
4*a*.—Angular aspect.
4*b*.—Lateral aspect.
5.—Oral aspect.
6.—Transverse section of aboral portion of test.

FIG. 7. —Verneuilina recurvata, sp. nov., x 44.
a.—Angular aspect.
b.—Oral aspect.

FIG. 8. —Uvigerina selseyensis, Heron-Allen & Earland, x 73.
a.—Angular aspect.
b.—Lateral aspect.
c.—Oral aspect.

FIG. 9. —Uvigerina selseyensis, Heron-Allen & Earland, x 73.
a.—Lateral aspect.
b.—Angular aspect.
c.—Oral aspect.

FIG. 10. —Bolivina intermedia, sp. nov., x 64.
a.—Lateral aspect.
b.—Oral aspect.

FIG. 11. —Lagena flexicollis, sp. nov., x 64.
a.—Lateral aspect.
b.—Oral aspect.
c.—Basal aspect.

FIG. 12. —Lagena striatopunctata, var. caudata, nov., x 64.
a.—Lateral aspect.
b.—Oral aspect.

FIG. 13. —Nodosaria glans, d'Orbigny, x 31.
a.—Lateral aspect.
b.—Oral aspect.

PLATE IV.

FIG. 1. —Nodosaria rostrata, sequenza, x 36.

FIGS. 2, 3 —Ellipsoidina lorifera, sp. nov., x 36.
2*a*.—Lateral aspect.
2*b*.—Oral aspect.
3.—Longitudinal section.

FIG. 4. —Nodosaria raphanistrum, (Linné). Transverse section, x 21.

FIG. 5. —Nodosaria soluta, Reuss, x 21.

FIG. 6. —Nodosaria oligostegia, Reuss, x 21.

FIG. 7. —Nodosaria consobrina, d'Orbigny, x 21.

FIGS. 8, 9. —Nodosaria pauperata, d'Orbigny, x 21.

FIGS. 10, 11.— ,, ,, var. bulbosa, nov., x 21.

FIGS. 12, 13.— ,, ,, var. crassisepta, nov., x 21.

FIGS. 14, 15.—Nodosaria pauperata, d'Orbigny, x 21.
Specimens showing mixed characteristics of several varieties.

FIG. 16. —Nodosaria adolphina, d'Orbigny, x 21. Smooth variety.

PLATE V.

FIG. 1. —Lingulinopsis acutimargo, sp. nov., x 36.
a.—Lateral aspect.
b.—Oral aspect.

FIG. 2. —Marginulina pyramidale, (Reuss), var. globosa, nov., x 31.
Four different aspects of the same specimen.

FIG. 3. —Marginulina behmi, (Reuss), x 36. Megalospheric form.
a.—Lateral aspect.
b.—Frontal aspect.

FIG. 4. —Marginulina behmi, (Reuss), x 36. Microspheric form.
a.—Lateral aspect.
b.—Frontal aspect.

FIGS. 5, 6. —Vaginulina recta, var. parallela, nov., x 31.
a.—Lateral aspect.
b.—Peripheral aspect.

FIG. 7. —Frondicularia ferruginea, Terquem, x 21.

FIG. 8. — ,, arborescens, sp. nov., x 36.

FIG. 9. — ,, ,, ,, x 44.

FIGS. 10, 11. —Cristellaria asperula, Gümbel, x 25.
a.—Lateral aspect.
b.—Peripheral aspect.

PLATE VI.

FIG. 1. —Cristellaria robusta, sp. nov., x 25.
a.—Peripheral aspect.
b.—Lateral aspect.

FIG. 2. —Cristellaria budensis, (Hantken), x 31.
a.—Lateral aspect.
b.—Peripheral aspect.

FIG. 3. —Siphogenerina sulcata, sp. nov., x 64.
a.—Lateral aspect.
b.—Oral aspect.

FIG. 4. —Bigenerina conica, Heron-Allen & Earland, x 64.
a.—Lateral aspect.
b.—Oral aspect.

FIG. 5. —Bigenerina selseyensis, Heron-Allen & Earland, x 73.
a.—Lateral aspect.
b.—Oral aspect.

FIG. 6. —Spirillina selseyensis, Heron-Allen & Earland, x 64.
a, *b.*—Lateral aspects.
c.—Peripheral aspect.

FIG. 7. —Chapmania gassinensis, Silvestri, x 31.
Much worn specimen.

FIGS. 8, 9. —Halkyardia minima, (Liebus), x 36.
a.—Superior aspect.
b.—Inferior aspect.
c.—Peripheral aspect.
9.—Vertical section.

FIGS. 10, 11.—Halkyardia ovata, sp. nov., x 36.
a.—Superior aspect.
b.—Inferior aspect.
11.—Young specimen.

FIG. 12. —Halkyardia ovata, sp. nov., x 64.
Diagrammatic horizontal section.

PLATE VII.

FIG. 1.—Linderina brugesii, Schlumberger.
Vertical section, after Schlumberger, x 83.

FIG. 2.—Discorbina opercularis, var. elegans, nov., x 62.
a.—Superior aspect.
b.—Inferior aspect.
c.—Peripheral aspect.

FIG. 3.—Discorbina compressa, sp. nov., x 29.
a.—Superior aspect.
b.—Inferior aspect.
c.—Peripheral aspect.

FIG. 4.—Pulvinulina acutimargo, sp. nov., x 29.
a.—Superior aspect.
b.—Inferior aspect.
c.—Peripheral aspect.

FIG. 5.—Pulvinulina karsteni, var. parva, nov., x 75.
a.—Superior aspect.
b.—Inferior aspect.
c.—Peripheral aspect.

FIG. 6.—Pulvinulina haueri, var. crassa, nov., x 21.
a.—Superior aspect.
b.—Inferior aspect.
c.—Peripheral aspect.

FIG. 7.—Amphistegina lessonii, d'Orbigny, x 25.

FIG. 8.—Spirillina selseyensis, Heron-Allen & Earland, x 62.
a, *b*.—Lateral aspects of a young specimen.

PLATE VIII.

FIG. 1.—Miliolina angularis, Howchin, x 29.
a, *b*.—Lateral aspects.
c.—Oral aspect.

FIG. 2.—Miliolina angularis, Howchin, transverse section, x 29.

FIG. 3.—Iridia diaphana, Heron-Allen & Earland, x 21.
a.—Superior aspect.
b, *c*.—Lateral aspects.

FIG. 4.—Irida diaphana, Heron-Allen & Earland, x 25.
a.—Lateral aspect.
b.—Broken specimen showing interior.

FIG. 5.—Virgulina lineata, sp. nov., x 62.

FIG. 6.—Chapmania gassinensis, Silvestri, x 37.
Inferior surface of unabraded specimen.

FIG. 7.—Chapmania gassinensis, Silvestri, x 29.
a.—Lateral aspect.
b.—Abraded and broken base of same specimen.

FIG. 8.—Pulvinulina erinacea, Karrer, x 50.
a.—Superior aspect.
b.—Inferior aspect.
c.—Peripheral aspect.

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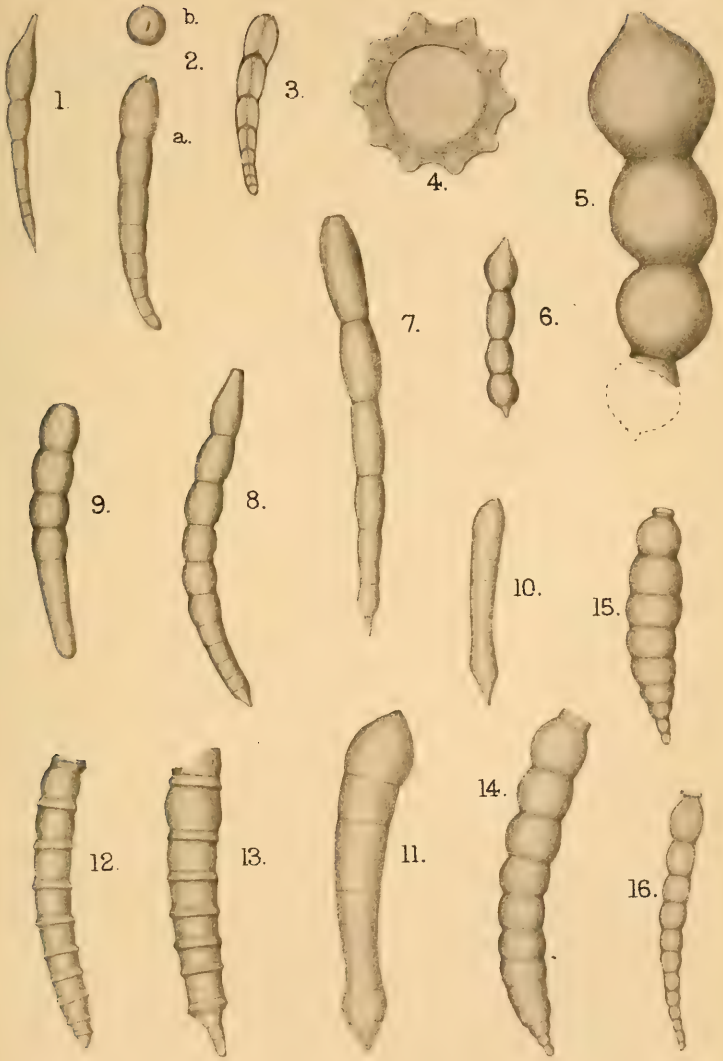

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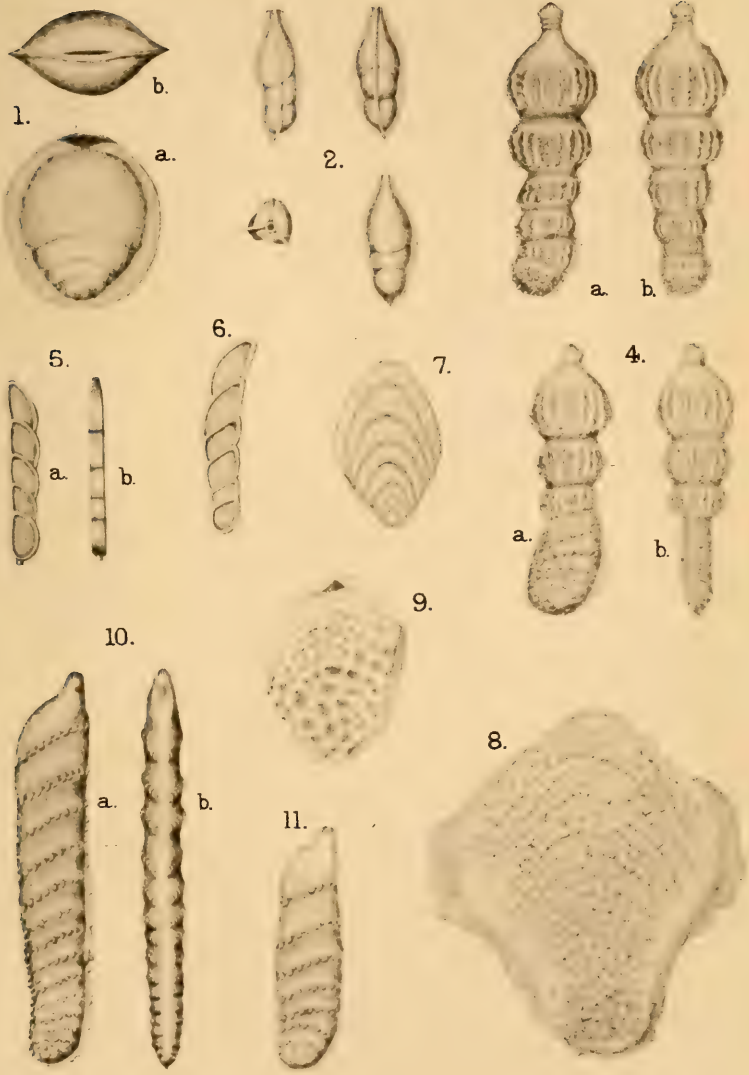

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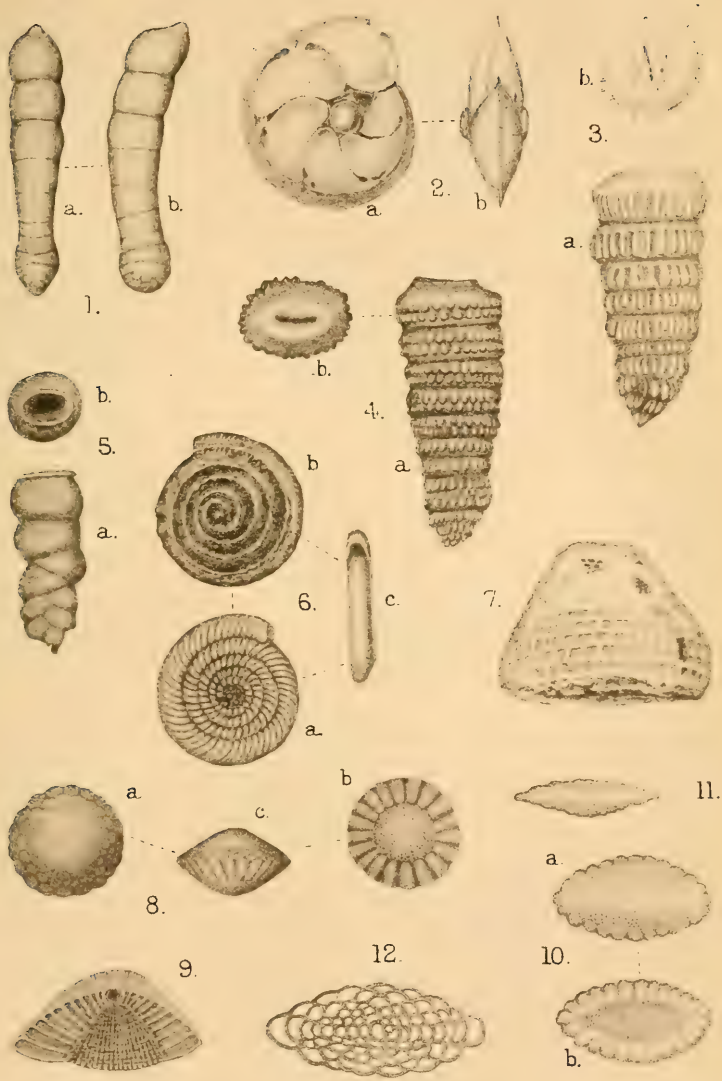

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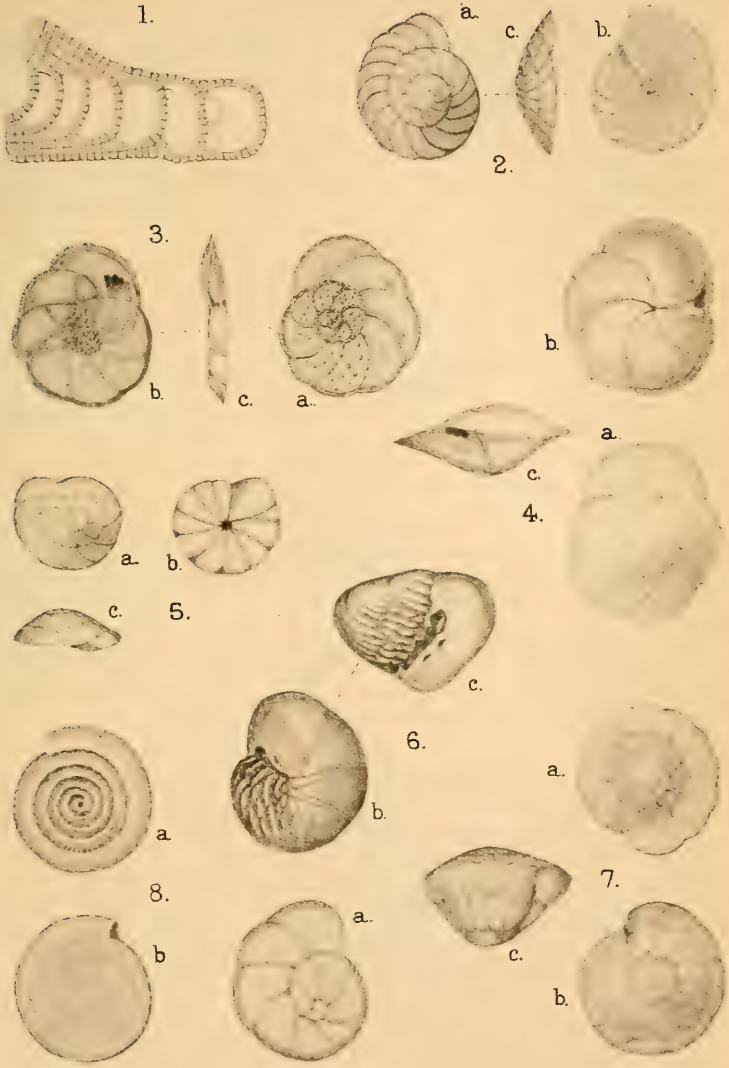

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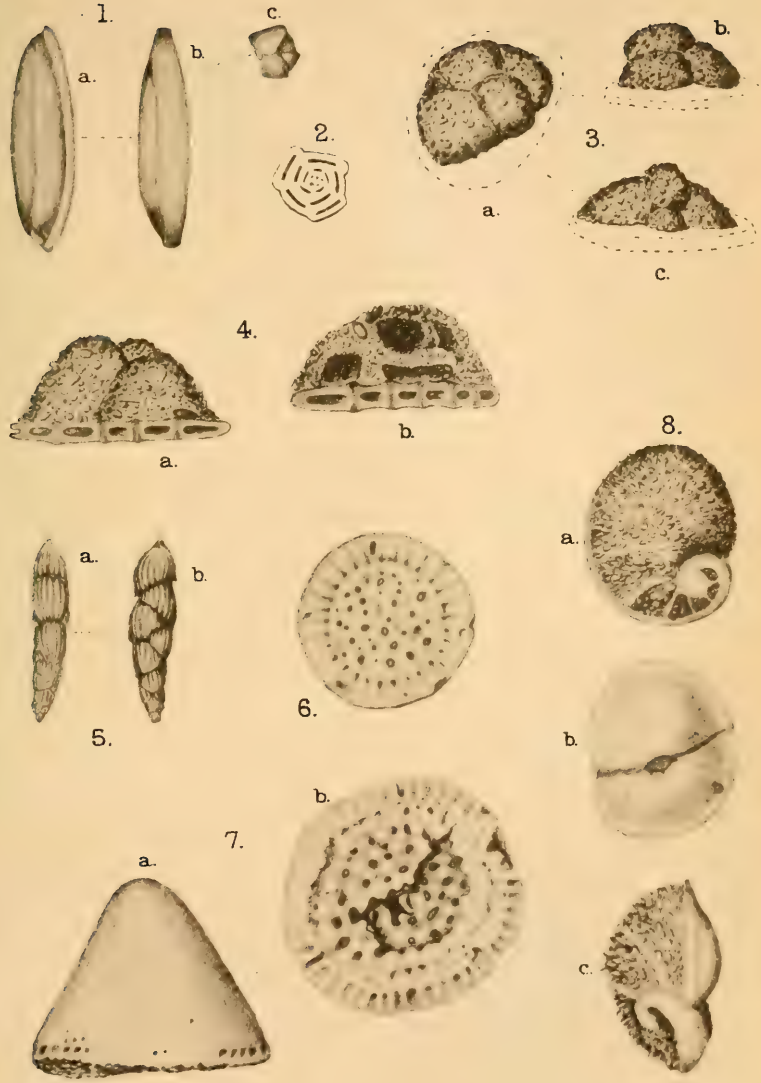
1.
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a.
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a.
b.
c.

BIARRITZ.

Showing Halkyard's Localities. Scale, $\frac{1}{10,560} = 416\frac{1}{2}$ feet to 1 inch.

Note.—Hachured lines mark cliffs, stippled surface shows sand exposed at low water.

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VII. The Occurrence of Cavernularia Lütkenii, Köll. in the Seas of Natal.

By J. Stuart Thomson, M.Sc., Ph.D., F.R.S.E.

Lecturer in Zoology in the Victoria University of Manchester.

(With one text-figure and two plates).

Genus Cavernularia Valenciennes.

Cavernularia Milne-Edwards & Haime. Hist. nat. Coralliaires, 1857, Vol. I. p. 219.
Cavernularia + Sarcobelemnon Herklots. Polypiers nageurs, 1858, p. 25.
Cavernularia + Stylobelemon Kölliker. Die Pennatuliden. 1872, pp. 336 and 348.
Fusticularia Simpson. Ann. N. H. 1905, p. 561, Pl. XVIII.

In a paper on the Pennatulacea of the Cape of Good Hope and Natal contributed to the Memoirs and Proceedings of the Manchester Literary and Philosophical Society I gave an account of those forms collected by the Cape Government trawler, the *Pieter Faure*. In preparing a second paper on the Alcyonaceous species from the same locality, I find that I have overlooked two specimens of Cavernularia Lütkenii, Köll. and I therefore now record this species from Natal and add descriptive notes.

The two parts, the stalk and the rachis pass almost imperceptibly into one another, on the latter numerous autozooids occur, with many siphonozooids between them. The smaller specimen has contracted in such a manner that the rachis which in the larger example is more or less hemispherical, is rather club-shaped. The stalk is soft and bladder-like; the colour of the specimens is cream.

The stalk of the larger specimen is 40 mm. in length, 6 by 7 mm. in diameter near the apex, 11 mm. at the middle of its length and much narrower at the base. The rachis of the larger specimen is 34 mm. in length, and its greatest diameter, namely, near the middle of its length, is about 33 mm. The autozooids are very delicate, and almost transparent. In the

contracted condition, they have an 8-lobed appearance with an aperture in the centre. The tentacles are delicate and have 7 or 8 pairs of pinnules, the latter being smaller towards the base.

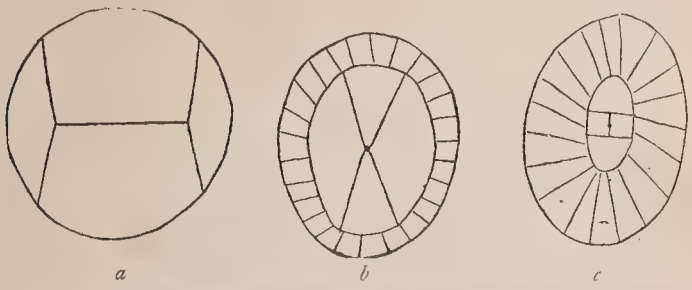

Fig. 1. Showing the arrangement of the septa and position of the axis.

The anthocodial part of the autozooid has apparently no spicules, and may be 3 mm. in length and 2 mm. in diameter. Some of the autozooids contain mature ova. In the contracted condition, the diameter of an autozooid is about 1 mm., that of a siphonozooid 0.015 mm.

The siphonozooids are remarkably transparent, and so numerous that it is difficult to estimate their relative number as compared with the autozooids, but at one part, there were 30-35 siphonozooids between 4 autozooids. The siphonozooids are surrounded by a ring-like layer of spicules. At the base of the rachis, in the transitional part between the latter and the stalk, young autozooids are present, along with numerous siphonozooids between them.

A transverse section near the base of the stalk shows two large and two small compartments (text-figure 1a), higher up beneath the base of the rachis, the four compartments become more equal in size. At the base of the rachis, there is an oval central space divided into four nearly equal compartments, with a rather soft axis in the centre, and the cavities of the autozooids grouped externally around the four spaces (text-fig. 1b). In the head at a still higher level, the relative size of the four cavities alters, and one has the condition shown in text-fig. 1c.

The axis, which is situated in the centre of the upper part of the stalk and the lower part of the rachis, is a thin rod-like structure, at one part 1 mm. in diameter; it appears to commence as a central stiffening at the internal ends of the four septa.

There are numerous small spicules on the surface of the stalk and rachis, others are situated on the walls at the bases of the autozooids tangential to the surface. The spicules of the external surface of the stalk which are placed more or less at right angles to the surface, are (a) minute, oval flattened discs, (b) similar forms but much longer. The smaller spicules are from 0.04 × 0.02 to 0.10 × 0.04 mm., in size; the longer forms are from 0.14 × 0.04 to 0.58 × 0.06 mm.; the latter spicules are more rod-like than the former and are brown instead of cream. On the outside of the polyp-bearing part or rachis, the spicules are rod-like, club-like, wart-like and there are also crosses and other more irregular forms. These spicules vary very much in size, they are sometimes from 0.06 × 0.02 to 0.484 × 0.06 mm. The spicules from the interior of the rachis between the bases of the autozooids are as a rule much larger than the preceding, frequently about 0.50 × 0.10 mm. in dimensions. The size of the spicules does not appear to be a point of much specific importance as it is so varied. A marked characteristic of many of the spicules is the occurrence of well defined lines of growth. A point which I wish to find out later, when I have more specimens is how these lines of growth vary in specimens of different size and age.

This species was first described by Kölliker from the Bay of Bengal. Thomson and Simpson have also recorded it from the Indian Ocean, namely from the Orissa Coast, from Sandheads, R. Hughli and from Calicut.

Hickson's definition of the genus Cavernularia is "Colonies usually club-shaped with small and usually completely retractile autozooids. Spicules of rachis rod-shaped and occasionally branched at their extremities. No spicules in the tentacles of the autozooids and rarely *(C. pusilla)* in the body walls of the anthocodiæ. Axis frequently absent, sometimes abbreviated, rarely complete." There is, however, an oversight in Hickson's table of the species of Cavernularia in which he states that C. lütkenii has a complete axis. Kölliker's diagnosis of Cavernularia Lütkenii was as follows:—Stock klein, keulenförmig. Kolben 2½ mal so lang als der Stiel, und fast doppelt so breit. Polypen klein, entferntstehend, braun, ohne Kalknadeln. Zooide zahlreich, farblos. Stiel mit dicker, in Kalkkörpern sehr reicher Cutis und wenig entwickelten, in Kalkkörpern sehr armen Muskellagen. Axe drehrund, im oberen Theile des Stieles und in der unteren Hälfte des Kolbens gelegen. Kolben mit vielen Kalknadeln bis in die Septa der Hauptkanäle hinein. Kalkkörper mehr weniger abgeplattet, im Stiele länglichrund, spindel — oder keulenförmig, 0.03 —

0.19 mm. lang, 0.013 — 0.044 mm. breit, die des Kolbens Walzen—, spindel — oder kolbenförmig ohne Theilungen an den Enden, 0.11 — 0.31 mm. lang, 0.01 — 0.06 mm. breit."

The following different species of the genus Cavernularia have been described:—*C. obesa* M.E. & H. 1857; C. elegans Herklots 1858; *C. Chuni* Kükenthal and Broch, 1911; *C. Herdmanni* Simpson, 1905; *C. madeirensis* Studer, 1878; *C. Habereri* Moroff, 1902; C. marquesarum Balss, 1910; *C. glans* Köll., 1872; *C. malabarica* Fowler, 1894; *C. orientalis* Th. & S., 1909; *C. andamanensis* Th. & S., 1909; *C. Lütkenii Köll.*, 1872; *C. pusilla Herklots*, 1858; *C. clavata* K. & B., 1911.

This species has considerable superficial resemblance with *Cavernularia glans*, Köll. as figured by Kükenthal in the "Valdivia" results. It also comes near *Cavernularia obesa*, Milne-Edwards & Haime and *C. Habereri, Moroff.* From the former it may be distinguished by the presence of an axis in the interior of the stalk, from the latter by the occurrence of spicules in the middle region of the cortex of the rachis.

The special interest in recording this species is that it occurs off the Coast of Natal and that the other specimens which were recorded by Kölliker and by Thomson and Simpson were taken farther north in the Indian Ocean. It is well known that the coast of Natal is washed by a warm current (Mozambique) from the Indian Ocean. This species has, however, not been found to occur on the West Coast of South Africa which is washed by the cold polar or Benguela current, and its habitat is within the 20 degrees isotherm of August as shown in physical maps.

The Genus Cavernularia belongs to the family Veretillidæ, the other genera belonging to this family being Lituaria Valenciennes, Veretillum Cuvier and Actinoptilum Kükenthal.

The general characters of the family Veretillidæ are the following:—Zooids evenly distributed on all sides of the rachis, the latter without external signs of bilateral symmetry. The colonies stout, club shaped or cylindrical, the autozooids and siphonozooids without any definite arrangement in horizontal or longitudinal rows. The spicules, double clubs or "capstans," spheres or ovals, flat plates or rods, minute otolith-like corpuscles or altogether absent. Axis extending the entire length, or short and incomplete or absent.

It is interesting that at first sight I regarded this form as one of the Alcyonacea, as Hickson in his recent monograph on the Siboga Pennatulids has brought forward the view that

the genus Cavernularia comes near the ancestral form of Pennatulaceæ, and that in the Alcyonaceous genera, Sarcophytum and Anthomastus we have Alcyonaceæ which show certain features of resemblance to a Veretillid. I had not read Professor Hickson's Monograph at that time, but it is curious that I had thought, at first sight, that my form belonged to the Alcyonaceæ and either to the genus Sarcophytum or to Anthomastus. It is possibly, however, only a case of convergence.

Locality, etc.:—"Pieter Faure" No. 11437A—Off the South Head of the Tugela River. Depth 12—14 fathoms. Collected by shrimp trawl. Nature of bottom, mud. Date of collection, January 16th, 1901.

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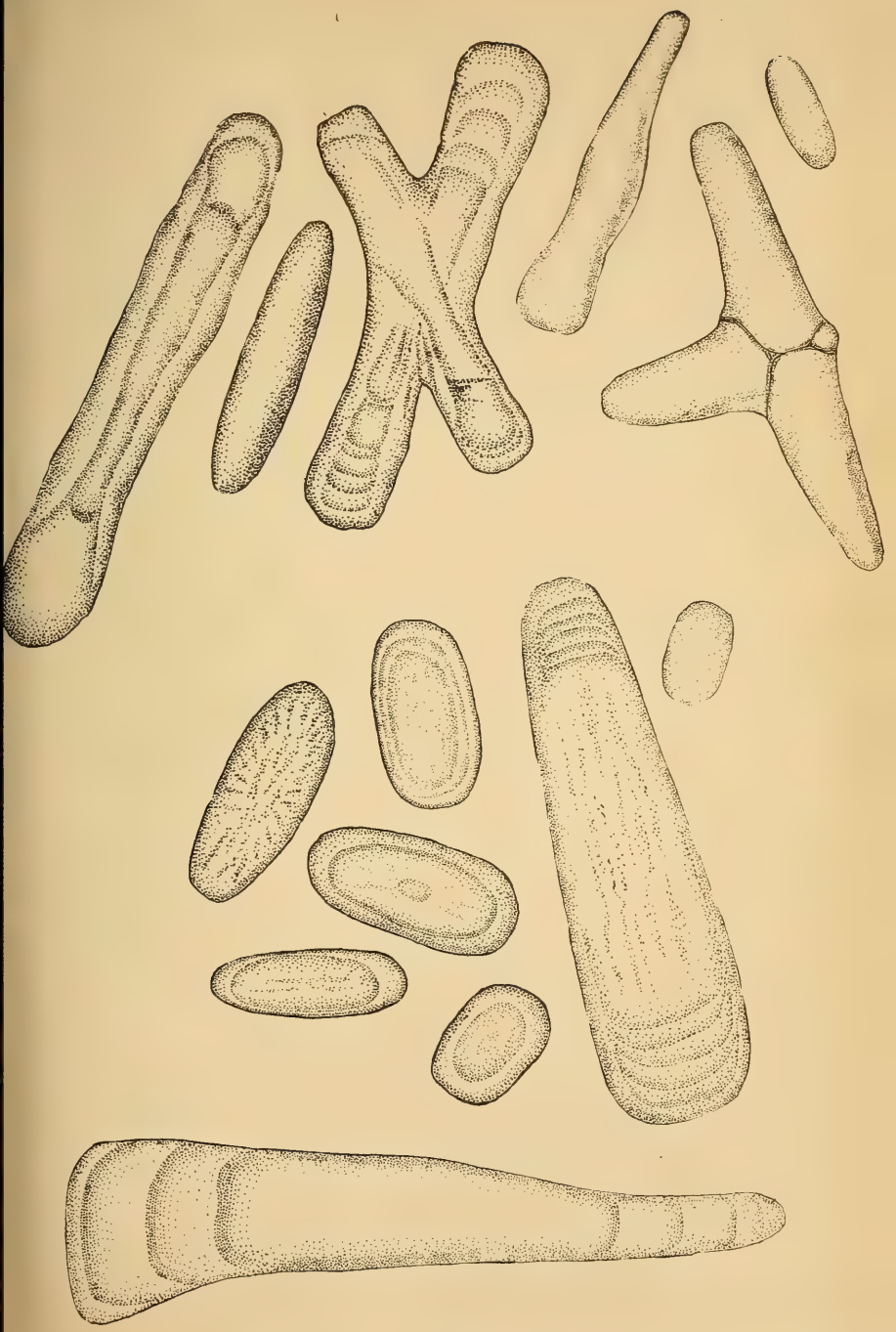
Cavernularia Lütkenii, Köll., n.s.



Spicules of Cavernularia Lütkenii, Köll.
Upper group from rachis, lower group from peduncle

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VIII. Regional Distribution of the Native Flora in Teneriffe.

By J. H. Salter, D.Sc.

(*Communicated by Professor F. E. Weiss, D.Sc., F.L.S., F.R.S.*)

(*Read November 13th, 1917. Received for publication March 5th, 1918.*)

The island of Teneriffe, lying in latitude 28° N., longitude 16° W., is the largest of the Canarian group, having an area of 919 sq. m. (2352 sq. kils.). Occupying a median position in the Canarian archipelago, the flora of Teneriffe has less of a Saharan character than that of the eastern islands which lie much nearer to the African continent, while not quite so markedly Atlantic in character as that of the western islands (La Palma, Gomera and Hierro) which lie outside it. It results from the shape of the island that it has three stretches of coast: (1) facing N. to N.W., (2) an equally long stretch facing S.E., and (3) a shorter stretch facing S.W., but for the sake of simplicity No. 1 may be termed the north coast, Nos. 2 and 3 together the south coast. The salient structural feature of the island is the central ridge ("Cumbre"), which, originating near the Lighthouse, attains to about 950 m. in the Cumbre de Anaga, but is interrupted at the point where La Laguna, situated upon a broad saddle at a height of only 550 m., stands in the midst of a green oasis, the only wide, continuous and level stretch of cultivation in the island. Rising again at Esperanza, and now fringed with pines, the *cumbre* runs in a south-westerly direction as a "divide" of gradually increasing height, and at Pedro Gil, the pass by which Orotava communicates with Guïmar, is already some 2030 m. above sea-level. Continuing its course at a still higher elevation (2300 m.), it presently divides to form the encircling edge of a great saucer-shaped depression (some 13 kils. across), in the centre of which rises the cone of the Peak, the culminating point of the island. This depression, surrounding the base of the Peak, lying at a height of about 2135 m. (7000 ft.) and encircled upon its outer side by arid cliffs of basalt and trachyte, which in places rise a couple of thousand feet higher, forms the curious region known as the Cañadas. It follows from the position of the Peak that the downward slope, from the edge of the Cañadas to the sea, is much wider and less abrupt upon its southern than upon its northern side. This southern region, the Bandas del Sur, is a hot and arid district, much of it semi-desert. The flanks of the central ridge are everywhere furrowed by a series of rocky ravines (known as "barrancos"), extending to the sea and having apparently been formed by the action of streams. At the present day they are perfectly dry, at any rate in the coastal region, except at intervals of several years, when, as the result of an exceptional

fall of rain, they are for a few hours converted into water-courses once more.

General Character of Vegetation

The special interest of what Dr. Christ terms "diese wunderreichsten und liebreizendsten aller Floren" was recognised even before the date of Humboldt's visit (1799), when he found the Botanic Garden at Orotava already in existence. One is at once struck by the "evergreen" character of the native vegetation and by the large proportion of shrubby or arborescent forms. Amongst the latter, representative of genera which in Britain are wholly or chiefly herbaceous, are the following: — *Senecio* (*Cineraria*), five or six species; *Sonchus*, nine or ten species; *Convolvulus*, five or six species; *Echium*, four or five species; *Plantago*, one species; *Rumex*, one species, and *Euphorbia*, eight species. Add a large number of shrubby Compositæ not enumerated above and the numerous woody, branched species of *Sempervivum*.

Endemic forms constitute an unusually large proportion of the native flora. Taking Sauer's list as basis, we find 333 endemic species enumerated out of a total of 1250 Canarian plants—*i.e.* 27 per cent. But if casuals, denizens and cosmopolitan weeds be excluded, and if, with the Canarian group, we include Madeira and the Azores, the proportion rises to 50 per cent. Certain genera stand out strikingly in this respect, the genus *Sempervivum* (as now divided into *Aichryson, Æonium and Greenovia*) presenting an extraordinary case. This may be shown concisely as follows, the denominator of the fraction indicating the number of Canarian species, and the numerator showing how many of these are endemic:—*Genista*, $\frac{5}{8}$; *Polycarpæa*, $\frac{5}{6}$; *Sempervivum*, $\frac{42}{43}$; *Argyranthemum*, $\frac{6}{6}$; *Senecio* (of Cineraria section), $\frac{14}{14}$; *Sonchus* (arborescent), $\frac{11}{13}$; *Convolvulus* (non-herbaceous), $\frac{9}{11}$; *Echium*, $\frac{11}{13}$; *Bystropogon*, $\frac{7}{7}$; *Micromeria*, $\frac{15}{17}$; *Sideritis*, $\frac{8}{9}$; *Statice*, $\frac{12}{14}$; and *Euphorbia* (non-herbaceous), $\frac{9}{9}$. It is instructive to compare in this respect two important Natural Orders, both largely represented in the Canarian group: (1) Leguminosæ with 120 species. The bulk of these are small vetches and trefoils of wide distribution, so that of endemic forms we find only three species of *Dorycnium*, two of *Vicia* (*V. filicaulis* and *V. cirrhosa*, thread-like and all but leafless) and five of *Lotus*, of which only three occur in Teneriffe. On the other hand, (2), the Compositæ are still more largely represented by about 170 species, of which no less than 80 are endemic.

The native flora of Teneriffe is fortunately in no danger of extinction. Not more than one-seventh of the steep and rugged surface of the island is capable of cultivation. In the *barrancos*, upon the sea-cliffs, the old lava-flows and the rocky outcrops which everywhere occur, the indigeneous flora in varied and characteristic forms has it practically all its own way.

As Hooker points out, the Canarian flora generally, and this applies also to that of Teneriffe, contains many plants which are more nearly allied to Mediterranean species than to those found

in Morocco. This applies to such genera as *Ayperdeum*, *Cistus* and *Ephedra*. Some of the endemic forms have even a more distant relationship. *Ceropegia dichotoma* and *Dracæna Draco*, for example, have their nearest relatives in the East, the former in India, the latter in Socotra. This leads Engler, who bases his conclusions largely on Hooker's account of the flora of the Canarian archipelago, to consider this latter flora to represent in all probability the survival of the flora of the Tertiary period, a flora of a more tropical and Oriental character than the more xerophytic flora which to-day characterises North Africa and the Mediterranean region.

More puzzling is the occurrence of certain species which are obviously related to similar species belonging to the American flora. This applies to such genera as *Persea* and *Ocotea* (*Oreodaphne*).

Factors which have influenced the Character of the Native Flora

(1) Long isolation. Teneriffe has had no connection with the African continent within any recent geological epoch.

(2) Volcanic origin. The whole surface of the island is formed of the products of igneous action; basaltic and trachytic rocks, recent or weathered lava-flows, pumice, cinders, ash, in places a red loam of the nature of volcanic mud.

(3) Climate: dry, warm and sunny, and free from extremes of temperature. Rain, always insufficient in amount, falls between mid-October and mid-April, the remainder of the year being, as a rule, rainless. Steep slopes are everywhere the rule, so that rain runs off rapidly. Cultivation is only rendered possible by an elaborate system of irrigation. At the coast and up to moderate elevations (Villa Orotava, Guïmar, 300 m.) the lowest night temperatures in winter do not fall below 8° C. (46° F.), while maxima in summer rarely exceed 29·5° C. (85° F.). At Orotava the mean winter temperature is 17·5°C. (63° F.).

Factors inducing Variations in the Distribution of the Plant Life of the Island

(1) Great range in climatic conditions due to difference of altitude, from sea-level to the summit of the Peak, 3760 m. (12,192 ft.).

(2) Connected to some extent with this, variation in annual rainfall. The northern slope receives more than its share of the rain brought by the north-eastern trades. Thus at Orotava the annual rainfall is nearly sixteen inches, while at Guïmar, on the southern slope, it averages barely eleven inches. In winter the region of the cloud-belt is frequently wrapped in drizzling rain, while the coast is in full sunshine. Above the cloud-belt is another region of great atmospheric dryness, that of the Peak and Cañadas.

(3) Variations in the substratum. While the greater part of the island is covered by deposits due to eruptions of the Peak of comparatively recent geological date, its two extremities, the promontories of Anaga and Teno, are of much more ancient origin.

Their soil, often a fine red loam, retains more moisture than do the porous deposits (ash, lava, cinders, sand) characteristic of the remainder of the island. Anaga receives the first onfall of the rain-clouds brought by the north-east trades. Hence *Ranunculus cortusæfolius*, which at Guïmar is a plant of the moist *barrancos* (760 m.), grows near Taganana almost to sea-level and *Genista canariensis* descends noticeably lower than it does elsewhere. Both regions possess a number of plants which do not occur elsewhere in the island or are highly characteristic.

The Zones of Vegetation

Humboldt recognised four of these regions, proceeding from sea-level :

(1) (Zone of the Vine.) Characterised by tree-like species of *Euphorbia, Dracæna* and *Sempervivum*, and by shrubby species of *Sonchus*.

(2) (Zone of the *Monte Verde*.) Laurels, holly, arbutus, ferns.

(3) (Zone of the *Pinar*.) *Pinus canariensis*, with *Myrica faya* and *Erica arborea*.

(4) (Above the Tree Limit.) Retáma (*Spartocytisus*) and a few herbaceous plants and grasses.

Dr. Christ prefers a subdivision into three great belts :

(1) The Coast Region. From the seashore up to about 610 m. (2000 ft.). Characterised by the occurrence of *Opuntia*.

(2) The Cloud Region. Commonly occupied by the cloud-belt.

(3) The Alpine Region. Above the cloud-belt.

It will be seen that upon this view the cloud region corresponds to Nos. 2 and 3 of Humboldt's series, while both agree in recognising a coastal and an alpine region.

It is evident that the zones can only be characterised in general terms and that they are separated by no hard-and-fast lines. Thus if we accept Christ's coast region it must be with the proviso that the plants growing at sea-level are an entirely different series from those met with at the upper limit of this zone, where, immediately under the cloud-belt, cooler conditions prevail. No single species can be taken as giving an exact indication, since the range of nearly all extends higher upon the southern side of the central ridge than upon its northern slope. Thus *Opuntia*, which above Guïmar ceases at 730 m., was noticed at Vilaflor extending in a warm *barranco* up to the skirts of the pine forest, while *Euphorbia regis-Jubae* attained to very nearly the same level.

Taking the limit of the coastal belt upon the southern side of the island at 730 m. (2400 ft.), its composite nature may be shown by a subdivision as follows :—

(1) Foreshore.

(2) Desert (stony, rocky or black sand).

(3) Orchards, plantations, vineyards (banana, tomato, orange, vine).

(4) Cultivated lands (wheat, potatoes, lupins, broad beans).

No. 3 extends to about 396 m. (1300 ft.), which is the limit of the orange above Guïmar. No. 4 ceases at about 628 m. (2060 ft.), but isolated patches of cultivation are carried to a much higher level. The wide difference as regards vegetation presented by the coastal belt at its lower and at its upper limits will be further dealt with shortly. Upon the steeper northern slope, (2), the desert strip is much reduced or altogether absent.

The second of the great zones, that of the evergreen woods and moist shady *barrancos*, is a perfectly natural one, as is also that of the pine forest which succeeds it as we pass upward. Following upon this, the writer would recognise the zone of shrubby foliose Leguminosæ, two in number, *Cytisus prolifer*, the Escobón, and *Adenocarpus viscosus*, the Codéso. These, the chief fodder plants of the island, occupy wide tracts upon the higher slopes of the *cumbre*, immediately below the all but leafless *Spartocytisus nubigenus* with which shrubby vegetation ends.

A. The Coast Region and Lower Slopes to 730 m.

Much of the coast is of a steep and rocky nature. Wherever this is the case, the parsnip-like *Astydamia canariensis* occurs. Lower stretches of coast have a beach of black volcanic sand, upon which a furious surf usually beats. Immediately above this is a strip of *foreshore vegetation*, which, upon examination, is found to be more varied than at first appears, but is of a cosmopolitan character, consisting largely of small Chenopodiaceæ and representatives of allied orders, with such plants as *Mesembryanthemum crystallinum*, *Frankenia pulverulenta* and *lævis*, *Picridium crystallinum*, *Heliophytum erosum*, and *Euphorbia peplis* and *paralias*. *Argyranthemum frutescens* (the common Paris daisy) and one or two species of *Beta* alone represent the endemic flora. Here, too, is the curious succulent *Zygophyllum Fontanesii*, with each of its crowded leaves of the size and shape of a moschatel grape. In the immediate neighbourhood of the sea occur *Schizogyne sericea* (a Composite with silvery-white foliage), *Lycium afrum* and *Salsola oppositifolia*, further *Statice pectinata*, *Polycarpæa Teneriffæ* and *Forskohlea angustifolia* (Urticaceæ), the two last being endemic, while *Ifloga spicata*, allied to *Filago*, is of wider distribution.

Rising more or less abruptly from the coast there is upon the south side of the island a barren and almost waterless region, in places as much as 10 kils. in breadth. Much of this is a hopeless country entirely given up to *Opuntia* (*coccinellifera* and *Dillenii*). The former, cultivated at the time of the cochineal industry, is now a serious pest, as every detached segment lying upon the ground takes root. Here are stretches of loose black sand, hills of baked glazed slag or of volcanic cinders, old lava-flows and every variety of stony and gritty *malpais*. Very characteristic is the alternation of intensely hard layers (having a calcareous appearance) with loose pumice. Upon these " pavements " scarcely anything grows but the white cistus (*C. monspeliensis*), sometimes accompanied by the hoary,

thick-leaved *Helianthemum canariense.* From above Guïmar the two recent lava-flows of 1705-1706 are seen meandering through this desert country to the sea, supporting after two centuries scarcely any vegetation but a tufted lichen (*Stereocaulon*). Where a little water is available, parts of this coast desert are terraced for vines or tomatoes, but between Guïmar and Santa Cruz there is scarcely an orange-tree, while so hopeless is the country in the other direction that, on approaching Arona, one even welcomes the reappearance of *Opuntia.* Fig-trees, however, are more general and in the dry season remain the embodiment of greenness and shade. Old individuals cover a large area, the main branches bending downwards to take root and send up secondary stems from the points at which they touch the ground.

The native vegetation of the coast-belt, including the arid, rocky ravines which furrow it, illustrates every possible adaptation to semi-desert conditions. With the exception of the fresh green of *Plocama,* its general aspect is grey, many plants being either glaucous or covered with a silky, mealy or hoary pubescence. The leaves of others contain aromatic or acrid principles, while another group (*Sonchus spinosus, Lycium afrum*) depend for protection upon their tough, wiry nature and armament of spines. Reduction of leaf-surface is seen in *Reseda scoparia, Convolvulus scoparius* and in the numerous "switch plants," such as *Retáma Spachii, Plocama pendula, Sonchus leptocephalus, Linaria spartea* and *scoparia, Campylanthus salsoloides* and *Asparagus scoparius.* The plants of the sun-scorched *barrancos* are extremely deep-rooted and many (as the larger species of *Sempervivum*) only flower at the expense of nutriment accumulated in the course of several or of many years.

These characters are nowhere better seen than in the vegetation of the old lava-flow which has issued from the Montañeta de Guïmar. The latter is still a perfect cone, with the sides of its crater overgrown with vegetation. Here are vast thickets of the cactus-like *Euphorbia canariensis,* each stiff quadrangular column beset with four rows of spines. It is often overgrown by the climbing Asclepiad *Periploca lævigata,* known as "cornical," from its horn-like fruits. Intermixed with the thickets of *Euphorbia,* and profiting by the protection which they afford—no small matter when all-devouring goats everywhere range at large—are other desert shrubs such as *Sonchus leptocephalus,* the white-powdered, yellow-flowered *Cneorum pulverulentum, Messerschmidia fruticosa* (Boraginaceæ) and *Asparagus arboreus.*[1]

The curious Asclepiad *Ceropegia dichotoma* appears as a cluster of fleshy, upright, jointed meal-covered stems, having thus much the appearance of a bunch of wax candles. The few grasses, as *Aristida cœrulescens* and *Tricholæna Teneriffæ,* are of characteristically desert type. Near at hand upon the loose black sand *Plocama pendula*

[1] The following were also noticed here or elsewhere finding safety in a close association with *Euphorbia canariensis*:—*Rhamnus crenulata, Argyranthemum fœniculaceum, Kleinia nereifolia, Convolvulus floridus* and *Canarina campanula,* while *Statice imbricata* was seen growing under the protection of *Euphorbia regis-Jubæ.*

shows its graceful drooping shoots and *Sonchus spinosus* suggests a tangle of barbed wire. It has no foliage leaves after the seedling stage and is often spun up by *Cuscuta*. *Citrullus colocynthus*, with its gourds the size of oranges, straggles over the heated surface of this miniature Sahara. Of the leafy arborescent species of *Euphorbia*, *E. regis-Jubæ* and *E. balsamifera* are highly characteristic of this region, growing under favourable circumstances to 4 m. in height. In exposed situations upon the coast the latter species becomes prostrate, and the extraordinary appearance of a mass of writhing, fleshy arms presented by ancient specimens, leafless, contorted, riven and half dead, is as remarkable as any aspect of vegetation in the island. Very similar in appearance to *Euphorbia regis-Jubæ* is *Kleinia nereifolia*; it has the habit of a miniature dragon-tree and is in fact an arborescent *Senecio*.

Considerable uniformity marks the vegetation of this desert-belt, which is found bordering the whole of the south-eastern coast. It is prolonged up the south-western coast and even extends round the promontory of Teno to Buenavista on the northern coast, where all the plants mentioned, including *Ceropegia*, were seen in profusion, with the addition of the curious *Euphorbia aphylla*. From this point onward the steeper and comparatively well-watered slopes of the northern coast allow small scope for the development of the desert flora, but wherever conditions are favourable, as where a lava-flow has made its way down to the sea, the familiar forms reappear.

The genus *Statice*, nowhere better represented than in the Canaries, is characteristic of the northern coast. *S. arborescens*, the finest species, is no longer found in a wild state. *S. macrophylla*, little inferior to it, was met with on the coast of the Anaga promontory. Old plants form a woody stock 45 cm. in height, covered by the persistent bases of previous leaves.

In the remaining and upper part of the coastal region are comprised all the more fertile parts of the island, though upon the north side banana plantations descend in places almost to sea-level. This region owes such fertility as it possesses to careful distribution of the water drawn from rock-borings in the higher *barrancos*, and led for miles in a series of stone channels. But nowhere is cultivation more than partial, and where it fails, as in the dry, rocky ravines and on the old lava-flows, the native flora asserts itself. The Villa de Orotava and Guïmar, each standing at an elevation of about 330 m., but the one upon the northern and the other upon the southern slope of the central ridge, are excellent centres for the study of the vegetation of this sub-zone. The dependence of fertility upon water supply is nowhere more evident, the appearance of date-palms, maize, orange-trees or bananas invariably indicating the existence of a tank of *atarjea*. From the scorched, opuntia-grown slopes one drops into the depths of the Barranco Infierno to find a rivulet which might almost be a Hampshire trout stream so familiar is its vegetation of water-cress, *Helosciadum*, *Potamogeton* and water-ranunculus, with *Epilobium* and *Mentha* on its banks, but the illusion is dispelled by the tall thickets of *Arundo donax* and the huge leaves of *Colocasia*.

Of the large number of genera characteristic of this zone it is only possible to allude to a few, and it should be borne in mind that many of those which find their chief development here are almost equally at home at either a higher or a lower level.

Sempervivum. The flora of the island affords no more remarkable sight than that of the great leaf rosettes, 35 cm. in diameter, of *Æonium tabulæforme,* thickly studding the rocks above the coast-road near San Juan de la Rambla, or those of an allied species upon damp rocks above the Anaga lighthouse. Equally striking is *A. holochrysum* upon the tiled roofs in the Villa Orotava and the branched, woody *A. canariense* in the dry *barrancos* sending up its flowering stem to a height of three feet. Some species, as *A. barbatum* and *Smithii,* are characteristic of the south side of the island. *Aichryson hirtum* and *sub-pilosum* are annuals.

Sonchus. This is peculiarly the zone of the arborescent species of *Sonchus* (*S. jacquini, radicatus, gummifer, leptocephalus, arboreus*), popularly "bush" or "tree" dandelions. They attract the notice even of non-botanical visitors, especially when in flower from January to March.

Convolvulus. Of the non-scandent species, *C. floridus* is conspicuous upon the sides of the ravines on account of its masses of snowy flowers. The almost leafless *C. scoparius,* said to have become scarce owing to the former demand for its roots ("Canary Rosewood"), from which a perfume was distilled, was found to be still abundant near the seaward termination of the Ladera de Guïmar.

Echium. Several species (*E. gigantium, strictum, aculeatum*) are conspicuous shrubs of the dry *barrancos. Echium simplex,* the "Pride of Teneriffe," only found in the northern coast region of Anaga, sends up in May a single axis of inflorescence to a height of 6 to 8 feet.

Lavandula. L. stœchas, with conspicuous attractive bracts, was seen on dry downs above La Laguna. *L. abrotanoides* is everywhere ornamental in rough, rocky localities. *L. pinnata,* var. *Buchii,* is confined to the north coast.

Euphorbia. E. regis-Jubæ and *balsamifera,* before referred to, are almost equally characteristic of this zone. Another fine arborescent species is *E. atropurpurea,* with deep red floral bracts.

Dracæna. D. draco is chiefly seen at the present day as a specimen tree in gardens and public squares. Occasionally, as when clinging to the uppermost rocks near the sky-line at the head of the Barranco de Badajos or on cliffs below Taganana, it appears as an evident and striking element in the endemic flora. Since the destruction in 1867 of the world-famed example at Orotava, the dragon-tree at Icod (12¼ m. in circumference at 3 m. from the ground) is the largest in the island. There are other well-known specimens at La Laguna and at Realejo.

Ferns. Adapted to the driest of rocky situations are *Davallia canariensis, Notochlæna marantæ* and *vellea, Cheilanthes fragrans* and *Ceterach aureum.* The first-named loses its fronds at the commencement of the dry season; the others æstivate with shrivelled

and incurved fronds. *Adiantum reniforme, Asplenium canariense* and *hemionitis* also require little moisture, but prefer shade.

The following additional plants are characteristic of this zone, some of them, however, extending into the overlying one :—*Crambe strigosa* ; *Lavatera phœnicea* and *acerifolia* ; *Hypericum floribundum, canariense, glandulosum* and *reflexum* ; *Rhamnus crenulata* ; *Pistacia atlantica* ; *Lotus sessilifolius* and *dumetorum* ; *Retáma Spachii* ; *Polycarpœa carnosa, nivea* and *filifolia* ; *Paronychia canariensis* ; *Bryonia verrucosa* ; *Æonium,* several species in addition to those mentioned—*e.g. A. urbicum* ; *Bupleurum aciphyllum* ; *Ferula Linkii* ; *Rubia fruticosa* ; *Pterocephalus virens* (Dipsaceæ) ; *Phagnalon umbelliforme, saxatile* and *rupestre* ; *Inula viscosa* ; *Allagopappus dichotomus* ; *Astericus spinosus* ; *Argyranthemum frutescens* and *gracile* ; *Gonospermum fruticosum* ; *Artemisia canariensis* ; *Senecio tussilaginis* and *echinatus* ; *Tolpis coronopifolia* and *laciniata* ; *Andryala pinnatifida* ; *Picridium tingitanum* ; *Withania aristata* and *frutescens* (Solanaceæ) ; *Adhatoda hyssopifolia* (Acanthaceæ) ; *Micromeria varia* ; *Salvia canariensis* ; *Globularia salicina* ; *Plantago arborescens* ; *Achyranthus argentea* (Amarantaceæ) ; *Bosia yervamora* (Chenopodiaceæ) ; *Rumex lunaria* ; *Urtica stachyoides, Parietaria filamentosa* ; *Dracunculus canariensis* ; *Habenaria tridactylites* ; *Pancratium canariense* ; *Asparagus scoparius, umbellatus* and *albus* ; *Asphodelus ramosus* and *fistulosus* ; *Scilla maritima* ; *Avena uniflora* ; *Trisetum neglectum,* var. *canariense.*

Weeds (Casuals, Aliens, Denizens, etc.) of the Coast Region

An attempt to classify the " weeds " (in a broad sense) of the road-sides, cultivated lands and waste places brings out clearly the fact that the Canaries have received contributions from the most varied regions, but that the Mediterranean and North African element strongly predominates, while endemic forms are almost entirely wanting.

(1) Cosmopolitan :

Fumaria (*officinalis,* etc.), *Silene inflata, Calendula arvensis, Bidens pilosa, Plantago major* and *lanceolata.*

(2) Mediterranean and North African :

Sisymbrium millefolium, Koniga maritima, Helianthemum guttatum, Erodium (various species), *Fagonia cretica, Psoralea bituminosa, Medicago* (various species), *Mesembryanthemum crystallinum, Centaurea melitensis* and *calcitrapa, Cinara horrida, Scolymus maculatus* and *hispanicus, Wahlenbergia lobelioides, Convolvulus althæoides* and *Siculus* ; *Datura metel, Echium violaccum, Cynoglossum pictum, Anchusa italica, Linaria græca, Salvia ægyptiaca, Plantago* (various species), *Lamarckia aurea.*

(3) Subtropical and various :

Sida rhombifolia and *carpinifolia, Oxalis cernua, Acacia Farnesiana, Cassia* (two species), *Gomphocarpus fruticosus, Asclepias curassavica, Nicotiana glauca, Ricinus communis, Aloe vulgaris, Oxalis cernua,* of which the double-flowered form, reproduced by

bulbils, also occurs, causes the uplands of La Laguna to glow with colour. *Nicotiana glauca*, from the Argentine, flourishes everywhere, becoming a shrub and sometimes a small tree. *Ricinus communis* grows to the size of a small orchard tree and forms a woody trunk 40 cm. in diameter.

B.—The Cloud Region

This is characterised by woods and thickets of evergreens ("Monte Verde"), with pine-forest ("Pinar") above. This region of greater rainfall and more permanent moisture commences at about 730 m. (2400 ft.). The *Monte Verde* extends roughly to 1220 m. (4000 ft.). Above this the *Pinar*, where not destroyed, occupies more or less of the next two thousand feet, and may exceptionally push its outposts to a much higher level (uppermost pines at base of the Sombrerito above Vilaflor at 2400 m.—*i.e.* 7874 ft.). As the cloud-girdle usually extends from about 700 m. to 1600 m. (2300 to 5300 ft.), the *raison d'être* of the *Monte Verde* is evident. Its lower portion is encroached upon by cultivation (corn, lupins, beans), which extends up to 1000 m. (3280 ft.). Groves and plantations of Spanish chestnuts (*Castanea*) and peach and almond orchards have also been made at the expense of the *Monte Verde*. The region of chestnut groves is familiar to those Orotava tourists who make the ascent to Agua Mansa, 1185 m. (3890 ft.). With a cooler and fresher air, they note the appearance of sweet violets, water-cress, broom (*Sarothamnus*), *Fragaria vesca*, *Taraxacum dens-leonis*, *Myosotis sylvatica*, of bramble-thickets and brake-fern. Like the broom, the gorse (*Ulex europæus*) is said to have reached the island from Madeira. It covers the Mesa de Mota (760 m.) above La Laguna, and as one goes west is seen not unfrequently but locally and in small amount.

The *Monte Verde* is most richly developed in the coolness, moisture and shade of the deep *barrancos*. Ferns, mosses, liverworts and lichens are abundant in this dripping region, where only are still to be found vestiges of the laurel woods formerly of much wider extent.

The open slopes, on the other hand, are overgrown with cistus (the white-flowered *C. monspeliensis*, and *C. vaginatus* with large rose-coloured flowers) and tree-heath (*Erica arborea*), with a large admixture of *Pteris aquilina*. Attached to the roots of the cistus is everywhere seen the orange and red parasite, *Cylinus hypocystis*. Here, too, are grassy slopes which in April are at their most flowery stage, to which bushes of *Ononis laxiflora*, tall regiments of *Asphodelus ramosus*, masses of a *Lathyrus* resembling *sylvestris* and the purple stars of *Romulea grandiscapa* chiefly contribute. There is nothing else in the island which suggests the Alpine pastures.

The *Monte Verde* at the present day is far from being a continuous belt, but where it occurs the two species of *Cistus*, the native holly (*Ilex canariensis*), *Erica arborea* and *Myrica faya* (the

candleberry myrtle) will usually be found to be amongst its chief constituents.

Of the native Laurineæ, *Laurus canariensis* is a predominant feature only in the evergreen woods of Teno and of Anaga. It forms the bulk of the laurel woods of Monte Aguirre and of Las Mercedes near La Laguna. *Ocotea* (*Oreodaphne*) *fœtens*, the "til," with its acorn-like fruit, is now restricted to the Barrancos Castro and Ruiz. The writer visited the grove of ancient "tils" in the latter locality. In habit they resemble pollard beeches or hornbeams of wide girth. With them was seen *Phœbe barbusana*, which was also noted near Tegueste and fringing the edge of a *barranco* at La Florida above Orotava. The demand for its wood has no doubt rendered it scarce. To see the fourth and last of the group of native laurels, *Persea indica*, to perfection, one must visit one or other of the specially favourable localities where the *Monte Verde* is most varied and luxuriant. Such are the woods through which one descends to Taganana and the patch of forest at Agua Garcia above Tacoronte. Here *Persea indica* reaches a height of from 25 to 30 m., with a circumference of 6 to 8 m. at 2 m. from the ground. *Davallia canariensis* grows on the trunks and lateral limbs of the laurels, enlacing them with its brown-scaled rhizomes. *Erica arborea* here attains to a size seen nowhere else in the island, specimen trees being 20 m. in height and 70 cm. in diameter. The woods of Agua Garcia are further noted as being the only locality in the island where the large-leaved holly (*Ilex platyphylla*) occurs.

A variety of the olive (*Olea europæa*, var. *cerasiformis*) is not uncommon, but is nowhere cultivated. To the same natural order belongs *Picconia excelsa*, the "palo blanco"—*i.e.* "white wood"—now very scarce. The same may be said of two endemic representatives of the order Myrsinaceæ. *Heberdenia excelsa* is an evergreen tree of which examples may be seen near Buenavista. *Pleiomeris canariensis* has magnolia-like foliage; it was noted at Taganana, Barranco Ruiz and above Los Silos. Both have edible fruits and are sometimes cultivated. *Visnea mocanera* (Ternstrœmiaceæ), whose specific name perpetuates that by which it was known to the aborigines of the island, is a neat evergreen shrub, or occasionally a tree. Its cream-white flowers are musk-scented and the calyx-segments enlarged to enclose the fruit. *Catha cassinoides* (Celastrineæ) is of rather infrequent occurrence. Much more general are *Rhamnus glandulosa*, *Viburnum rugosum* and *Jasminum pumilum*. *Phyllis nobla* and the rarer *P. viscosa* are endemic representatives of a peculiar genus of *Rubiaceæ*, while *Gesnouinia arborea* is a shrubby *Parietaria*.

In the cool depths of the Barranco del Rio, above Guïmar, many botanists have studied the vegetation of this zone, nowhere more rich and varied than here. This ravine is the chief stronghold in the island of *Arbutus canariensis*, seen elsewhere very sparsely and in the form of isolated individuals. Here there are still some hundreds of trees, the older ones 9 m. or more in height and with trunks 60 cm. in diameter. Their smooth stems and limbs of rich cinnamon-brown

contrast with their long, glossy, peach-like leaves and racemes of rose-tinted flowers. Here also amongst the thickets occurs *Jasminum Barrelieri* (*odoratissimum*), well known in cultivation. The Canarian ivy trails from the rocks. To the steep walls of the chasm cling *Semele* (*Ruscus*) *androgynus* and *Genista canariensis*, while *Convolvulus canariensis* and *Tamus edulis* twine over all. Moist hollows are full of *Cystopteris fragilis* and *Adiantum capillus-veneris*. Early in the year when the fine buttercup, *Ranunculus cortusæfolius*, flowers, the herbaceous flora of the *barranco* is at its best. The climbing *Canarina campanula* then shows its large dull red bells variegated with orange. One of the most striking of Canarian plants, it is not generally common, though in Anaga so abundant that it is there cut by the armful for fodder. *Senecio Heritieri*, a shrubby, downy-leaved "cineraria," now flowers, to be followed later by the annual *S. cruenta*, origin of the cultivated cinerarias. Several herbaceous orchids (*Orchis patens*, *Tinæa cylindrica*, *Ophrys bombyliflora*, *Platanthera diphylla*) occur in the shady thickets, which are a tangle of *Myrica faya*, *Rubus fruticosus*, var. *canariensis*, and shrubby species of *Hypericum*. In shade is also found the curious little umbellifer *Drusa oppositifolia*, beset with minute hooks, while *Tinguarra cerviariæfolia*, a large coarse-leaved member of the same natural order, is seen upon the rock ledges. A little later flowers *Ixanthus viscosus* (Gentianaceæ), resembling a large *Chlora*, and the Canarian fox-glove (*Isoplexis canariensis*) sends up its tall spikes of orange-red flowers. *Pteris arguta* is characteristic of the moist depths of this, as of other *barrancos*, while more sparingly *Woodwardia radicans* spreads its seven-foot fronds.

In the evergreen woods of Teno which look down upon the wide vale of Palmar, in mid-winter verdant with young corn, ferns (chiefly *Aspidium canariense*) were as luxuriant as in Devonshire coombes, while the mosses and *Polypodium vulgare* upon the walls, the grey rock and driving mist, strongly recalled Wales. *Athyrium umbrosum* is the glory of the Taganana woods, where also, as at Agua Garcia, *Trichomanes radicans* was met with. *Hymenophyllum* occurs, but is rare. *Selaginella denticulata* carpets every damp rock face. *Lotus peliorhynchus*, the "Pico de Paloma," most beautiful of its genus, with silvery linear leaflets and orange-crimson flowers, is so much in request that it is almost extirpated as a wild plant. *Bencomia caudata* and *moquiniana*, both scarce, are allied to and resemble *Poterium*. The genus *Sempervivum* is almost as well represented in this zone as in the one below it. Especially remarkable is *Æonium canariense*, which sometimes completely covers rock faces with its great wide-spreading rosettes. The members of the genus *Petrophyes* (*Monanthes*) are succulents of small size, *P. polyphyllum* resembling a miniature *Sempervivum arachnoideum*.

The peculiar flora of this zone of evergreen woods and thickets is in general much better developed upon the northern than upon the southern slope of the central ridge, as might be anticipated from the greater rainfall which there prevails. Especially is this the case in the Anaga peninsula. Here, upon the Cumbre de Anaga, *Erica*

scoparia replaces the otherwise ubiquitous *E. arborea*. *Lomaria spicant*, abundant here, was not seen elsewhere. Here also *Dicksonia culcita*, the only tree-fern of Teneriffe, occurs in heath thickets in the Valle de las Palmas. *Sambucus palmensis* is found only upon the northern slope, where also are the sole localities for *Salvia Bolleana* and for several endemic species of *Scrophularia*. *Luzula canariensis* and *Carex Perraudieri* were noted only in the moist woods above Taganana.

The hot, dry slopes of the southern side of the island, overlooking the Bandas del Sur, are unfavourable to vegetation of this type. Hence, when Guïmar is left behind, the *Monte Verde* becomes practically non-existent or is represented solely by wide stretches of *Cistus*. Near Vilaflor it is only in the depths of the *barrancos*, where a little water remains throughout the summer, that one meets with a stray bush of *Erica* or *Visnea*, a little *Salix canariensis* or *Pteris arguta*, with rarely a solitary laurel or arbutus, to recall the bush flora which characterises this zone in more favoured parts of the island. If laurel woods ever existed here, they have long since been destroyed. Corresponding with, and perhaps partly the result of, this failure of shade and moisture loving forms, there is here an upward extension of the range of many plants which belong, strictly speaking, to the coastal region below. This has already been remarked in the case of *Opuntia* and *Euphorbia regis-Jubæ*. Further examples are afforded by *Retáma Spachii*, *Ferula Linkii*, *Gonospermum fruticosum*, one or more of the arborescent species of *Sonchus*, *Echium strictum* and *Asparagus scoparius*, which are noted upon the rocky sides of the ravines, while in their depths are found forms more appropriate to this elevation of 1200-1500 m. The result is an intermixture which here renders the demarcation of the zones almost impossible.

The Pine Forest

Pinus canariensis is a tree often of noble growth and of peculiarly light and graceful appearance, owing to the length (often 25 cm.) of its slender "needles," which are of a more lively green than those of our familiar *P. sylvestris*. The natural position of the *pinar* is immediately above that of the *Monte Verde*, hence towards its lower limit the pines are often scattered amongst thickets of *Erica arborea*, *Ilex*, *Cistus* and *Myrica faya*. The largest pines in the island are two specimens known as "los pinos grandes" upon the Lomo Gordo above Vilaflor. Their trunks at 2 m. from the ground are 10 m. in circumference, their height 35-40 m. (say 130 ft.).

Owing to four centuries of wasteful destruction, the *pinar*, as a well-marked belt, no longer exists. From much of the area which it formerly occupied it has completely disappeared, or only a few isolated individuals have escaped the woodman and charcoal-burner. The resulting decrease in the rainfall of the island is only too evident. There is no attempt at re-afforestation. Quantities of seedlings spring up, only to be destroyed by the herds of goats which everywhere roam at large. Upon the northern side there are considerable

stretches of *pinar* above Icod and La Guancha, elsewhere but scant remains. Thus in crossing from Orotava to Guïmar one reaches the divide at Pedro Gil without having passed half-a-dozen pines. Upon the southern side of the island matters are rather better. Above Arafo and Guïmar there are some good patches of forest, and farther to the south-west, above Granadilla and Vilaflor, pines of the finest growth, cresting rocky ridges and fringing deep ravines, give to the scenery almost an alpine character. Yet even here there are vast stretches of sun-scorched waste which were forest-clad only a century ago. The pines above Vilaflor are rooted in arid red trachyte, apparently without admixture of loam.

Just as in the lower part of the *pinar* there is a large admixture of heath and cistus, so towards its upper limit, as the pines thin out, we reach a zone where two leguminous shrubs, the chief fodder-plants of the island, predominate over all other forms of vegetation. They are *Cytisus prolifer*, the *escobón*, silvery-leaved and white-flowered, and *Adenocarpus viscosus*, the *codéso*, with flowers of the same golden-yellow as the gorse. Above the Guïmar *pinar* there are many hundreds of acres occupied by these two plants, the *escobón* being often a small tree. Above Arafo the writer met with extensive and impenetrable thickets of *codéso* ten feet in height. It is probable that the destruction of the forests has led to a large extension of the area thus occupied. The shrubby species of *Hypericum* are still much at home at this level, as are also the various specis of *Sideritis* (*S. canariensis, candicans*, etc.), whose leaves and stems are covered with a white woolly down, and the members of the more anomalous labiate genus *Bystropogon* (*B. plumosus, canariensis. odoratissimus*). The latter are aromatic shrubs with masses of small, inconspicuous flowers. Both genera are highly characteristic of the endemic flora. The " sempervivums " of the genus *Greenovia* flourish at this elevation. Luxuriant masses of the largest species, *G. aurea*, cover the moist rocks upon the Orotava side a short distance below the Pass of Pedro Gil. It was upon the flanks of the Peak in this sub-zone, amongst *Cytisus, Bystropogon* and scattered pines, that the latest volcanic outbreak in the island, that of November, 1909, occurred. The following plants, not previously alluded to, are also characteristic of the zone of the *monte verde* and *pinar* or are restricted to it: — *Cheiranthus mutabilis, Sisymbrium millefolium*; *Geranium anemonefolium*; *Vicia cirrhosa*; *Polycarpæa latifolia*; *Pimpinella dendroselinum*; *Todaroa aurea* and *montana*; *Rubia peregrina*; *Argyranthemum fœniculaceum, Pyrethrum ptarmicæfolium, Senecio multiflorus* and *appendiculatus, Carlina salicifolia, Centaurea Webbiana* and *canariensis*; *Convolvulus fruticulosus* and *variabilis*; *Echium virescens* and *lineolatum*; *Cedronella canariensis*; *Daphne gnidium*; *Urtica morifolia*; *Smilax canariensis*; *Agrostis canariensis*.

C.—Above the Clouds

This uppermost region commences at about 2000 m. (6500 ft.), where the ridgy back of the *cumbre* stands clear above the cloud-

curtain. It culminates in the cone of the Peak, which overlooks the desolate region of the Cañadas. We have here a rarefied atmosphere of great clearness, strong insolation by day with rapid fall of temperature after sunset, great atmospheric dryness and a decided winter, more or less snow lying upon the Peak from November till April. Stretches of loose pumice, cones of cinders, scorched cliffs of lava are lit up by a glare of sunshine which renders the shadows correspondingly deep and well-defined. Here, where, reasoning from experience, we might expect a vegetation similar to that of the Alps, we find but the scantiest trace of such a flora. There is in fact no soil to support one. The only plant with a familiar Alpine facies is *Arabis albida*. The characteristic plant of these high-lying wastes is the broom-like *Retáma* (*Spartocytisus nubigenus*), dark, rigid and leafless throughout the winter, clothing itself with silvery-grey foliage in early spring and breaking out into masses of snowy blossom in May. The *escobón* and *codéso* reach the Cañadas, but do not dispute them with the all-pervading *retáma*, whose upward range is, moreover, much greater. It dies out upon the Peak rather below the level of 3050 m. (10,000 ft.). The endemic *Viola cheiranthifolia* was found growing in the loose pumice of the Montaña Blanca, which flanks the base of the Peak, sending down its long tap-root deep into the substratum. Not a trace of other vegetation bore it company. *Silene nocteolens* was noted at 2740 m. on the Pico Viejo and *Chrysanthemum anethifolium* at about the same level. *Serratula canariensis* also occurs here, but is rare. No phanerogamic plant reaches the shelter-hut, 3262 m. (10,700 ft.), where it was difficult to find even a trace of lichen. At 3570 m. a moss, *Grimmia apocarpa*, was seen, maintained by condensation of moisture from a volcanic vent. In the crater itself (3760 m., 12912 ft.) a small quantity of a black crustaceous lichen was found with difficulty. A fine *Echium* (*E. auberianum*), with flower spikes four feet high, occurs at the base of the Riscos above Vilaflor. Here, also, ancient specimens of *Juniperus cedrus*, riven and contorted, are seen clinging to the crags. Elsewhere the demand for its wood has led to the complete eradication of the " cedro." *Rosa canina*, var. *Armidæ*, was seen at the Pass of Guajara, 2436 m. Two species of *Sorbus* are said to occur. The " sempervivums " find here their last representative in *Greenovia rupifragum* and *G. aizoon*. *Mentha sylvestris*, var. *Teydea*, marked the line of a slender runnel of water fed by one of the rare springs of this all but rainless region. Several weeds of the lower levels, *Lotus campylocladus*, *Psoralea bituminosa*, *Wahlenbergia lobelioides*, with a few scattered grasses (*Aira*, *Festuca*), growing amongst the *retáma*, slightly redeem the poverty of this scanty flora which, however, further embraces the following :—*Cheiranthus scoparius* ; *Rhamnus integrifolia* ; *Polycarpaea aristata* ; *Pimpinella Buchii* ; *Pterocephalus lasiospermus* ; *Senecio palmensis* ; *Carlina xeranthemoides* ; *Tolpis Webbii* ; *Scrophularia glabrata* ; *Micromeria julianoides* ; *Plantago Webbii* ; *Oryzopsis cœrulescens*, var. *Teneriffæ*, and a fern, *Cheilanthes guanchica*.

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The writer is indebted to Dr. Burchard of Orotava for assistance in determining the names of the plants which he collected.

Vegetation in the old crater of the Montañita, Guïmar.

Dracæna draco at Guïmar.

The Peak from the Cañadas, showing rétama.

The Riscos above Guïmar, with belt of pine fores.

IX. The Association of Facetted Pebbles with Glacial Deposits.

By J. Wilfrid Jackson, F.G.S.

(*Assistant Keeper of the Manchester Museum* (*Geological Department*)

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INTRODUCTION

The object of this paper is to place on record some recent discoveries of facetted and wind-eroded pebbles in Lancashire and Cheshire, and to discuss the interesting association of such pebbles with Glacial deposits.

Wind-worn and facetted pebbles have been regarded as somewhat rare in the British Isles; but this may be due to their being overlooked. The records of their occurrence, especially in association with the Drift, are certainly scanty.

Probably the earliest discovery in England was made by the late Mr. R. D. Darbishire, of Manchester, nearly fifty years ago, when a beautifully facetted pebble of quartzite was obtained from the Glacial sand and gravel of Bowdon, Cheshire. This specimen was an exceedingly perfect and characteristic example of the pyramid pebbles or "Dreikanter," such as are found in the "Diluvium" of the North German plain. It was exhibited by Dr. F. A. Bather before the Geological Society of London in 1899, and was fully described by him later in the *Proceedings of the Geologists' Association of London*.[1] The same writer has since described another distinctly facetted pebble of micaceous sandstone found by Mr. W. D. Brown, of Burscough, near Ormskirk, Lancashire, in gravelly soil overlying Boulder-clay at about 3 feet below the surface in the Burscough Brick Company's clay pit.[2]

In 1912 Mr. Brown recorded a number of other examples from the same clay-pit, including a large specimen, 8 by 8 inches, and 4 inches high, weight 11½ lbs., which he states "was found *in situ* embedded in the clay, 40 feet from the land surface."[3] This specimen is distinctly three-edged and is almost identical in form to the Bowdon pebble. It has been presented to the Manchester Museum by Mr. Brown. The depth at which it was found is remarkable. The facet angles appear to be somewhat rubbed, as if the specimen had been rolled about after the facetting.

[1] F. A. Bather, "Wind-Worn Pebbles in the British Isles," *Proc. Geol. Assoc.*, XVI., June, 1900, pp. 396-420, Pl. XI.

[2] *Geol. Mag.*, August, 1905, pp. 358-359; and W. D. Brown, *Lancashire Naturalist*, October, 1912, p. 259.

[3] Brown, *op. cit.*, p. 259 and plate.

The Manchester Museum also possesses a series of pebbles (mainly quartzite) worn by natural sand-blast, which were obtained from Drift overlying Bunter Sandstone, near Ramsdale Ho., Notts, by Mr. H. S. Holden.

A further interesting record is that of Mr. L. J. Wills, who refers to the occurrence of wind-worn pebbles in high-level gravel, near Bromsgrove, Worcestershire.[1] Here they formed a prominent feature of a deposit overlying Lower Keuper Sandstone, at about 350 feet above sea-level. This fact is of interest in connection with the Pendleton series described in the present paper.

Two other interesting occurrences are cited in the discussion of a paper on "The Keuper Marls around Charnwood," by Mr. T. O. Bosworth.[2] Dr. C. A. Matley there states that "he had found dreikanters as surface specimens in the marl country near Birmingham." Mr. E. E. L. Dixon also refers to dreikanters which he had picked up on the surface near Lichfield, where they appeared to be numerous. Though he had originally thought that they might have been derived from adjacent Triassic outcrops, either directly or by way of Glacial Drift, he was prepared, after discussion, to accept the view that they were chiselled during a dry epoch of the Pleistocene.[3]

A selection of some of the wind-etched pebbles dealt with in subsequent pages was exhibited in 1916 before the Geological Society of London,[4] and later before this Society.[5]

For the convenience of description it will be advisable to divide this communication into two parts :

1. The Distribution of Facetted Drift Pebbles in the Manchester and Wirral Districts.
2. The Geological Horizon and Significance of the Facetted Pebbles.

1. The Distribution of Facetted Drift Pebbles in the Manchester and Wirral Districts

During the construction of new roads for building extensions in the higher parts of Pendleton, Lancashire, the western side of a moraine-like hill has been cut into, exposing an excellent section of current-bedded and faulted Glacial sands and gravel. The position of the site, known as the Claremont Sand Pits, is : Lat. 53° 29′ 52″ ; Long. 2° 18′ 43″ W. It is situated on the west side of Claremont Road,[6] about a third of a mile south of Irlams o' th' Height ; the altitude is between 200′ and 225′ O.D.

This hill, which overlooks the lower land to the S.W., W. and N.W., forms part of a series of similar moraine-like hills, ranging northwards, and bordering the valley of the River Irwell.

[1] *Geol. Mag.*, July, 1910, pp. 299-302, Pl. XXV.
[2] *Quart. Journ. Geol. Soc.*, Vol. LXVIII., 1912, pp. 281-294.
[3] *Ibid.* (Discussion, p. 294.)
[4] *Proc. Geol. Soc.*, 17th November 1916.
[5] *Proc. Manch. Lit. and Phil. Soc.*, Vol. LXI., Pt. I., 17th July 1917.
[6] Known as Height Lane on the old Survey maps.

The materials of which these hills are chiefly composed belong to the Drift deposit No. 2 of Binney's 1847 classification,[1] and are the so-called " middle sand and gravel " of various authors.[2]

On first being exposed, the Pendleton section showed a depth varying from 6 to 20 feet, according to the slope of the hill and the inclination of the new road (Light Oaks Road) cutting through the Drift mound in a westerly direction. On the northern side of this road, and in another running from it northwards, the beds consisted, in descending order, of a small thickness (about 2 feet) of grass-covered sandy soil, dark in colour, and containing, at the base, scattered flint cores and flakes, including a few " pigmies." These scanty remains are insufficient to furnish conclusive evidence as to date ; but they possibly indicate a Neolithic floor. This is rendered probable from similar occurrences elsewhere (see p. 6).

Below the soil-bed came a bed of lighter coloured sand, which, like the overlying soil, was noticeably devoid of stratification. This zone was about 2 feet in thickness and rested immediately upon a thick series of current-bedded Glacial sands with lenticular beds of small gravel and rolled coal-pebbles, and, in places, lenticular patches and layers of loam, the whole being much faulted. The Glacial sands themselves were remarkably free from stones.

On the southern side of Light Oaks Road the section, except for some weathering, is at present much the same as when first exposed. It differs considerably from that of the opposite side. At the Claremont Road end the beds consist of sand and gravel, but farther west, about the position of the 200-foot contour-line on the 6-inch Ordnance Survey map, reddish clay with rounded stones replaces the sand and gravel as a surface deposit. The clay occurs in bands of varying thickness, separated by thin layers of fine sand : it shows some contortion in places, and book-leaf layers are frequent. These beds rest immediately on current-bedded sands similar to those of the northern section. According to borings, made by the foreman in charge of the excavations, the greatest thickness of clay here is 5 feet 6 inches. This rests on some 30 feet of sharp sand entirely free from clay bands. This section is bisected by a short road running southward, and at one corner of this road a deposit of fine sand is seen filling what appears to be a slight depression or gully in the clay surface. Sand is also present overlying the clay in another portion of this road : this sand is apparently devoid of stratification.

The absence of the intervening deposits between the northern and southern sections (removed in making the road) renders it difficult to correlate the two sections with accuracy, but from the presence of a thin band of clay near the top of the sands at the lower or western end of the northern section one is led to the conclusion that the reddish clay rapidly thins out here. There was no trace of its extension over the sands at the eastern end before these beds were cleared away.

[1] *Manch. Lit. and Phil. Soc.*, Vol. VIII., 1847, p. 204.
[2] *Geol. Surv. Memoirs*, " Bolton," 1862 ; " Oldham," 1864, etc.

The most noteworthy feature of these deposits is the occurrence of large numbers of beautifully facetted and wind-worn pebbles in the sand-bed immediately below the soil-cap. These occurred *in situ* in a somewhat discontinuous layer, sometimes in nests or pockets, at a depth of some 3 or 4 feet from the original land surface. They were first noticed in the weathered talus of the section, but were ultimately located in the sand-bed below the soil-cap, and found to be strictly confined to that horizon. During the last two years I have collected several hundreds of these wind-worn pebbles from this zone as the exposure was cut back and the sand carted away for building and other purposes. They can still be obtained in numbers from the portions of the section still standing. They are not entirely restricted to the northern section, as I have obtained several characteristic examples from the sand occupying the gully in the surface of the clay of the southern section mentioned previously (p. 3).

The general field relations strongly suggest that the sand of the facetted pebble zone is definitely a post-Glacial deposit, probably the result of redistribution by wind before a soil-cap with vegetation began to form, and that the contained pebbles were worn by sand-blast in post-Glacial times. The close association of this bed with the underlying Glacial Drift would seem to imply that no great interval of time can have intervened between the deposition of the two series.

The sand in the facetted pebble zone, in its natural condition, is somewhat dark in colour, but noticeably lighter than the overlying soil : it adheres strongly to the pebbles when damp. On drying it becomes very much lighter. On microscopic examination it is seen to consist largely of yellowish-coloured quartz in rounded and sub-angular grains, mixed with smaller grains of quartz and of various drift rocks.

The pebbles showing wind action are typical of the North-Western Drift, consisting of slate, granite (Eskdale and others), Ennerdale granophyre, Borrowdale volcanic tuffs and ashes, porphyries, quartzites, millstone grit, sandstones, chalk flints, carboniferous chert and other rocks.

The largest facetted pebble so far found measures $11\frac{1}{2} \cdot 8\frac{1}{4}$ inches, and is 7 inches high. Others are of varying dimensions down to half-an-inch in diameter. Without exception, all the pebbles collected from this zone, whether facetted or not, show evidence of wind action on their surfaces.

A close examination of these pebbles reveals several interesting features. They show all stages towards the formation of typical dreikanter, or three-edged stones. The most remarkable feature, however, is the large percentage of stones which have been fractured or split. In some cases large stones, both igneous and sedimentary, have been split in half ; in others quite a third of the original pebble has been broken off ; and in each case the fractured face exhibits most definite evidences of modification by blowing sand. In a few cases the rounded unsplit pebbles show traces of facetting ; but the

action of the wind has not been sufficient to produce anything like the beautifully sharp edges and faces seen in the fractured examples.

Though most of the stones have been split on one face only, usually along a joint or bedding plane in the case of the sedimentary rocks, there are others which have been split in various directions, and modification of these faces by sand-blast has resulted in the production of three- or even four-edged facetted pebbles.

The occurrence of these numerous modified split pebbles at Pendleton is interesting in point of view of the fact that similar examples have been recorded from various other localities both in Europe and in America.

The majority of the Pendleton facetted stones show a rounded water-worn base ; but others, including the large example mentioned previously, still retain very definite traces of Glacial striæ on their bases.

Several pebbles occurred in the sand completely inverted, and some show distinct traces of erosion on both sides—that is, they indicate wind action for a time with one side up, followed by similar action after the pebble had rolled over.

A number of the stones were orientated *in situ*, and in some of these the eroded fractured surface faced north-westwards, in others westwards, and in others again south-westwards—the directions of the present prevailing winds. But as these also show wind erosion on other parts, it does not definitely indicate that these were the particular winds which eroded them.

Differentiation, according to varying hardness and composition, is well displayed on the granites, porphyries, grits, etc., where the weaker constituents have been strongly eroded, leaving the stones with an irregularly pitted surface, in some cases over the whole upper surface of the pebble. On the volcanic ashes, inequalities in texture, imperceptible to the naked eye, have been searched out, with the result that the pebbles have a roughened surface consisting of minute pimples of harder material standing out in relief.

The facets are not absolutely plane surfaces ; they are usually somewhat concave, grooved, or fluted. The concavity may be in part original and owing to conchoidal fracture. The facets are variable in number : the majority of the stones present one face only—a modified split face ; others two or more. Some examples with flat tops show three, four, or even five incipient facets. On some stones, chiefly igneous, the grooving is of the nature of parallel series of elongated pits running transversely across the face and not at right angles to the edge (see Fig. 14). On such stones as these the facet angles are very irregular ; but on the quartzites and fine volcanic ashes the edges are much straighter and sharper. A fair proportion of the stones are elongate-oval and these usually possess a long median ridge, with occasionally two small ridges diverging from it at one end. Several small flat oblong pebbles, especially of quartzite, are interesting from the fact that they must originally have had fairly vertical sides ; these have been worn by blown sand, leaving the stones with two almost vertical sides and two somewhat

sloping ones. The bases, too, in some cases, have been undercut, and around the basal edges of some of the fine grits a series of vermiculate grooves is present.

With regard to the chert, this invariably occurs in rectangular blocks, the whole surface usually exhibiting a dull polish. Where fossils are present (Crinoid stems usually), these have been etched out, leaving the surface full of small holes.

A few of the stones, the andesites especially, are remarkable from the fact that the sand-blast appears to have encountered a joint or crack in the stone and this has been enlarged and cut down considerably, giving the stone the appearance of having been cut by a blunt saw.

It would be quite impossible to describe the various modifications seen in the different pebbles from the Pendleton section. A selection, therefore, has been made of the more striking examples in this prolific series, and these are figured on the accompanying plates (Figs. 1-14).

Since my Pendleton discovery I have found two other localities near Manchester which have yielded facetted and wind-worn pebbles. One is on Kersal Moor, about 1½ miles N.E. of the Pendleton site, and on the other side of the Irwell valley. The surface of the ground is here dotted over with similar moraine-like hills of Glacial sand and gravel, and on the S.W. slope of one of these—Sand Hill, altitude 250 feet above O.D.—I succeeded in finding about half a-dozen distinctly facetted Drift pebbles. Their occurrence here is an exact parallel to Pendleton, both as to position and from the fact that the pebbles which exhibit wind action have also been split or fractured. One specimen of fine grit was found *in situ* about 18 inches below the present disturbed surface—*i.e.* about 9 inches deep in the sands. The top-soil consists of about 9 inches of densely matted rootlets of grass mixed with dark sand, which contains, amongst other things, numerous chippings of flint and chert. Other facetted pebbles were found in the sand where the top-soil had been removed.

The presence of a Neolithic floor at this site was first brought to public notice in 1908 by the late Mr. C. Roeder, of Manchester, who found large quantities of flint cores, flakes, and scrapers, hæmatite, etc., also a stone spindle whorl, all obtained from the top-soil.[1]

A similar Neolithic floor is present on an adjacent hill known as Rainsough on which a " camp " is marked on the Ordnance maps. I have here met with identical flint and chert cores and flakes in the top-soil, but was unable to find any facetted pebbles owing to the dearth of suitable sections.

Compared with coastal sites, the shallowness of the soil above these Neolithic floors in these inland localities is a noteworthy feature.

The other site near Manchester lies about a mile south of the Pendleton locality, at Bolton Lodge sand quarry, off Eccles New Road, Weaste. Several wind-worn Drift pebbles were picked up here from the turned-up soil of an allotment overlying a small thickness of Boulder-clay, resting on Upper Mottled Sandstone. The site

[1] *Trans. Lancs. and Ches. Antiq. Soc.*, XXV., 1908.

faces south and overlooks the canalised portion of the River Irwell; the altitude is about 75 feet O.D.

Whilst on vacation last year in the Wirral district of Cheshire, I discovered three interesting occurrences of facetted pebbles in association with Glacial deposits. All are situated in the Hoylake neighbourhood. One of the sites lies between Caldy and West Kirby, on the Dee estuary. Here a few facetted Drift pebbles were obtained from the wind-blown sand overlying the cliffs of Boulder-clay. Another and more interesting site is at Hilbre Point, not many feet above sea-level. Wind-eroded pebbles, of Borrowdale and other rocks, were here encountered on, and embedded in, the surface of the Boulder-clay, overlying the Bunter Pebble-beds. Immediately above the zone of the eroded pebbles is a well-defined Neolithic floor underlying blown-sand. The most important and interesting discovery, however, was made at Dove Point, Meols. Pebbles of various North-Western Drift rocks, showing distinct evidence of wind erosion, were met with in profusion in the upper portion of the reddish Boulder-clay and in the lower part of an overlying layer of bluish clay, some distance out from the shore, and much below the level of an ordinary spring tide. The blue clay of the section is probably altered Boulder-clay. The sand content is chiefly in the form of well-rounded and fairly large grains of quartz. It underlies the Lower Peat and Forest-bed of the Cheshire coast.

The peculiar character of the pebbles occurring in the blue clay below the Lower Peat and Forest-bed at this locality seems to have been incidentally noticed by T. Mellard Reade, some seventeen years ago, but he attributed their shape to being "*glacially facetted.*" [1] Stones, it is true, are occasionally polished and facetted by glaciers, but these differ from those worn by sand-blast. The ground surface is flatter and generally exhibits characteristic glacial striæ; the harder and softer constituents, too, of the rock have not been differentiated. The Dove Point examples, however, exhibit all the characters of wind-eroded pebbles.

The only other indication I can find of the probable occurrence of wind-worn pebbles in the Wirral district is contained in a paper by W. T. Walker on "The Boulder-Clay of North Wirral." [2] In his description of the clay pit owned by the Moreton Brick Company, this author states that amongst the objects of interest in this pit are: "Tetrahedral pyramids and triangular prisms, and striated stones. These seem to be fairly abundant, and although many of the striations are undoubtedly caused by ice action, I would submit that some show evidence of wind-etching, and would on this account be classed as Dreikanters" (Walker, *op. cit.*, p. 322). Doubtless Mr. Walker's conjecture is the right one, but unfortunately he does not specify the position of the pebbles, whether at the surface of the Boulder-clay or otherwise. The clay pit lies about half-a-mile from the coast, and the land surface is not more than 12 or 15 feet above sea-level. It is situated about a mile and a half east of the Dove Point section.

[1] *Geol. Mag.*, March, 1900, p. 98.
[2] *Proc. Liverpool Geol. Soc.*, XI., Pt. IV., 1913, pp. 317-324.

Apart from the association of the Wirral facetted pebbles with Glacial deposits (in these cases the beds are said to be Upper Boulder-clay) is the further interesting fact that, as at Pendleton and Kersal Moor, the pebbles are mainly split or fractured stones, which have been modified by wind action.

2. The Geological Horizon and Significance of the Facetted Pebbles

As already pointed out, in the Pendleton and Kersal Moor localities the facetted and wind-worn pebbles occur in a well-defined zone overlying the Glacial deposits and immediately below a Neolithic floor. At Hilbre Point, in the Wirral, they are similarly situated as regards the Drift and Neolithic deposits, while at Dove Point, in the same neighbourhood, they overlie what is regarded as Upper Boulder-clay. Here, however, a whole series of beds occur superimposed above the facetted pebble zone, indicating important changes in the relation of land and sea in post-Glacial times. Some of these changes have undoubtedly taken place during Neolithic times. The general succession of these beds has been studied by C. E. de Rance, [1] T. Mellard Reade,[2] G. H. Morton,[3] and others. From these observers we learn that the area occupied by these interesting deposits extends over the coastal portions of Lancashire and Cheshire, forming a low-lying plain stretching inland for several miles. Its inner margin is fairly well defined by the 25-foot contour-line, but a large part of its surface is low ground below sea-level, the sea being kept out in some places by a long range of sand-dunes that fringe the coast-line, in others by artificial embankments.

The succession of the beds at Dove Point is given by Morton [4] as follows :—

(1) Blown Sand, 15 feet.
(2) Soil-bed, 2 feet.
(3) Peat-bed, 1 foot.
(4) Blue Clay, 1 foot.
(5) Upper Forest-bed, 3 feet.
(6) Blue Clay, 2 feet 6 inches.
(7) Lower Forest-bed, 1 foot.
(8) Boulder-clay.

The Leasowe Embankment has since been extended towards Hoylake and some of the upper beds have been covered up by it. The lower beds of the section have also suffered denudation by the

[1] De Rance, "On the Post-Glacial Deposits of Western Lancashire and Cheshire," *Quart. Journ. Geol. Soc.*, XXVI., 1870, pp. 655-668.

[2] T. M. Reade, "The Geology and Physics of the Post-Glacial Period, as shown in the Deposits and Organic Remains in Lancashire and Cheshire," *Proc. L'pool. Geol. Soc.*, 1871-1872, pp. 36-88. (Reprint, pp. 1-53.)

[3] G. H. Morton, *Geology of the Country around Liverpool*, second edition, London, 1897, pp. 228-272.

[4] Morton, *op. cit.*, p. 235, and Plate XVI., Fig. C.

encroachment of the sea, and very much of the Lower Forest-bed has been washed away.

According to Morton (*op. cit.*, p. 236), the spring tides cover the Upper Forest-bed 3 feet, while the Lower Forest-bed is about 8 feet below the level of an ordinary spring tide.

Much difficulty is experienced in tracing the Lower Forest-bed in other parts of the Mersey district owing to the large amount of denudation it appears to have undergone previous to the deposition of the overlying beds. Where visible, or where proved by borings, it generally rests on Boulder-clay, the upper part of which is of a bluish colour for a depth of 6 inches to 1 foot, caused by the abstraction of the peroxide of iron through the action of decomposed organic matter. Possibly this upper portion is to some extent redistributed Boulder-clay, as it is very full of pebbles. It is exposed at Dove Point, and is the bed from which I obtained the wind-eroded pebbles described in previous pages.

Regarding the contemporaneous human history connected with these deposits, the evidence is far from being as complete as could be desired. De Rance (*op. cit.*, p. 659) observes that no historical or natural remains have ever been found in the Lower Forest-bed, but that the oldest relics of man, consisting of implements of Neolithic age, have been met with in the lower clay and silt below the Upper Forest-bed.

There seems to be a general consensus of opinion that the Lower Forest-bed has yielded no evidence of man, and that the Roman and later antiquities found on the surface of the Upper Forest-bed have all been washed out of an overlying soil at the base of the sand-hills by the encroachment of the sea.

The position of the Lower Forest-bed with regard to the Glacial deposits is interesting in view of the fact that similar relations exist elsewhere in the British Isles. These relations have been dealt with in detail by Coffey and Praeger in their paper on "The Larne Raised Beach."[1] They regard the sequence displayed by the Belfast and Larne post-Glacial deposits as being in close agreement with similar series in Central Scotland, Northern England, and more especially in the Mersey area. In each of the areas dealt with by these authorities an identical series of beds appears to have been deposited on a former land surface of Boulder-clay. So close is the correspondence that the whole can be arranged in parallel columns.

The chief point of interest in connection with the Larne and Belfast deposits is the fact that some portions at least can be dated with a certain degree of accuracy, owing to the presence of Neolithic flint implements. These occur in nearly the whole thickness of the Larne beach deposits, and from this it is concluded that Neolithic man was on the ground during the submergence that allowed of the continued laying down of the Larne gravels. In the Belfast area the Neolithic period has been correlated with the upper portion of the estuarine clays, etc., overlying the oldest post-Glacial land surface

[1] *Proc. Roy. Irish Acad.*, Vol. XXV., Sect. C., No. 6, December, 1904, pp. 143-200, Pl. IV.-IX.

in the district, represented by a bed of peat, lying at a depth of some 28 feet below high-tide level.

Though the human evidence is so scanty in the case of the post-Glacial series of the Cheshire coast, there seems just reason to assume, from the analogous position of the estuarine series between the Lower and Upper Forest-beds to that of the Belfast section, that some portion at least is of Neolithic age. Unfortunately the well-defined Neolithic floors in this neighbourhood, at Red Noses, near New Brighton, and Hilbre Point, near Hoylake, do not lend any assistance in this correlation, as they are not definitely associated with the estuarine clay and forest-beds, both being situated on rocky eminences above the shore. They only tell us that Neolithic man was certainly present in the neighbourhood.

The geological horizon, therefore, of the facetted pebbles at Dove Point can safely be regarded as pre-Neolithic, as in the other cases dealt with.

The mode of occurrence shows that, both at Dove Point and other Wirral localities, and in the Manchester area, the pebbles were acted on by sand-blast after the deposition of the Glacial beds on which they lay, and in this respect they agree with similar pebbles found in North Germany and in North America, these being generally regarded as post-Glacial in age.

Resting on the Boulder-clay in certain places in the Liverpool district is a deposit of sand variously known as the Upper Drift Sand (Morton),[1] Washed Drift Sand (Reade),[2] and Shirdley Hill Sand (De Rance).[3] It is generally regarded by local geologists as a post-Glacial deposit and is considered to be a blown sand of earlier age than the marine silts and forest remains exposed on the coast. It is irregularly developed in the area between Southport and Garston, and is recorded inland as far as Bickerstaffe, Skelmersdale, Rainford and Kirkby. Its thickness is very variable, and, as might be expected from the nature of such a deposit, it occurs at times on high ground and not on low, and *vice versa*.[4] In some localities it is reported to rest on a basal gravel-bed.[5] Beds of peat are occasionally met with in this sand and an examination of this peat exposed at Aintree has yielded an interesting assemblage of plant remains which have been described in detail by W. G. Travis.[6]

The exact position of the Shirdley Hill Sand with regard to the Lower Forest-bed is not clear, but both Reade and Morton definitely place it below that horizon. It appears to be quite clear, however, that the sand is anterior in age to the period of submergence which

[1] Morton, *op. cit.*, p. 212.

[2] Reade, *op. cit.*, pp. 47-51.

[3] De Rance, *op. cit.*, pp. 662-663; *ibid.* "The Superficial Geology of the Country adjoining the Coasts of South-West Lancashire, 1877" (*Mem. Geol. Survey*).

[4] W. G. Travis, *Trans. Liverpool Botanical Society*, Vol. I., June, 1909, pp. 47-52; see also Geological Sketch Map by Harold Brodrick, in *British Assoc. Handbook to Southport*, 1903.

[5] Reade, *op. cit.*, p. 48.

[6] W. G. Travis, *op. cit.*, pp. 47-52.

allowed the accumulation of the deposits of mud and silt which underlie the Upper Forest-bed. Whether the pebble-bed at the base of this sand in various places can be correlated with the bed with facetted and wind-worn pebbles at Dove Point on the Wirral coast is uncertain, owing to the entire absence of the Shirdley Hill Sand at this locality. Its relative position, however, with regard to the Drift deposits is suggestive of such a correlation.

It is of some interest to note that the basal gravel-bed of the Shirdley Hill Sand and the bed with facetted pebbles at Dove Point appear to occupy a somewhat analogous position with regard to the Drift to that of the basement bed, or " Steinsohle," of the Loess of the North German plain, where facetted pebbles are of frequent occurrence. Whether such pebbles occur in association with the Shirdley Hill Sand has not been recorded.

From the foregoing remarks it seems legitimate to conclude that an intimate connection may exist between the period when the pebbles were eroded and the laying down of the Shirdley Hill Sand in early post-Glacial times, as the blown sand would provide the necessary medium for modifying the pebbles.

Having discussed the geological horizon of the facetted pebbles dealt with in this paper, we can pass on to the question of the significance of such pebbles.

That the various pebbles had been first fractured before being acted on by sand-blast is conclusively proved by the evidence of the pebbles themselves. The probable cause of this splitting might, therefore, be considered first.

Judging from the generally rounded and perfect condition of the stones embedded in the underlying Glacial Drift, it seems a reasonable assumption that the pebbles concerned must have been in a similar perfect condition when they were left at, or near, the bare surface of the Drift on the retreat of the ice. Such being the case, they would be subject to the varied atmospheric agencies which bring about the disintegration of rocks. Of these perhaps the most important are variations of temperature and alternations of frost and thaw.

The combined action of frost and thaw seems to provide a sufficient explanation for the splitting of pebbles left exposed on the bare surface of the Drift. It is possible that many of these Drift pebbles possessed incipient joints at the time they were carried along by the ice, and in this case continued exposure to alternations of frost and thaw would cause these joints to increase and result in the splitting or complete fracturing of the pebbles.

It is of some interest to note that at the Pendleton section I found several wind-worn pebbles lying about on the talus which had been split into two or three pieces during the frost of last winter. The pieces were lying together and the splitting was along joint- or bedding-planes (see Fig. 8). They were all sedimentary rocks; I saw no granites or igneous rocks so split, though such occur in abundance among the wind-worn pebbles obtained *in situ*, all of which show modification by sand-blast on their fractured faces.

Possibly there were more frequent variations in temperature during the period when these lay exposed at the surface of the Drift.

Dr. Bather, in his exhaustive paper on the subject of wind-worn pebbles (*op. cit.*, p. 401), refers to several writers who have attempted to explain at all events the main contours of facetted pebbles as due to the breaking up of rocks into angular fragments, but, he goes on to say, " we have yet to learn of a rock in which the joint-planes lie at the angles usual in pebbles facetted by blown-sand." The series dealt with in this paper show that such cases are definitely present (see Figs. 4 and 9). They also show that a typical Dreikanter form can be produced in this way. Though all the pebbles from the zone exhibit evidence of sand-blast, either in the form of polish or erosion, there is little evidence that any large face has actually been produced by wind and sand action.

We can now turn our attention to the interesting feature of wind-erosion and to a consideration of its significance. It has been argued by several writers on the subject that wind-worn pebbles imply desert, or, at least, steppe conditions. They have also been regarded as indicating uniform climatic, as well as geological relations, and that the conditions leading to their production must therefore have a similarly general significance. These statements are not altogether borne out by the evidence provided by the numerous occurrences, for, as Bather remarks (*op. cit.*, p. 411) : " Facetted and wind-polished pebbles have been found over almost all parts of the present surface of the earth, under tropical, temperate, and Arctic climates, on plains, on hills, or in valleys, scattered over steppes and deserts, or confined to small clearings in the midst of fertile fields and evergreen forests." He gives a list of a few recorded localities, as follows :—deserts of Libya and Arabia ; desert of Sinai ; Kalahari desert of S.W. Africa ; 16 kilometres from Walfisch Bay, S. Africa ; deserts of Central Asia ; Reval ; Schleswig-Holstein ; Jutland ; Anholt in Kattegat ; Silfåkra, near Lund, East Scania and N. of Fjelkinge, near Kristianstad ; Halland ; Iceland ; sandy plateau of Brenne, in France ; surface of old moraines near Lyon ; New Zealand, various localities [1] ; California ; Colorado ; Nebraska, Bad Lands ; New Jersey and Northern New York. To these are to be added the numerous localities in Germany, recorded in the papers by Berendt, Chelius, Geinitz, Gutbier, Wittich, and others.[2]

In Germany, it is true, facetted pebbles are scattered over a wide area, and their intimate association with the Loess, with its peculiar fauna, seems to imply a dry climate or steppe conditions, following on the retreat of the glaciers, when the North German Plain was covered with loose deposits as yet uncovered with vegetation. But the evidence in favour of steppe conditions obtaining in

[1] It is interesting to note that among the wind-worn pebbles from the Waitotara Grand Flats, near Wanganui, New Zealand, in the Manchester Museum, are one or two showing the beginning of wind-erosion on fractured surfaces.

[2] See Bather's paper, *op. cit.*, for references to literature.

this country in post-Glacial times is far from being of a satisfactory nature.

As already pointed out by Bather, facetted pebbles in themselves cannot be regarded as evidence of steppes, or of a dry climate. The conditions at the close of glaciation in any country must have been favourable to the production of such pebbles. The land was bare and exposed to winds ; its surface was strewn with boulders and pebbles, and associated with them was an abundance of sand. Coupled with the fact that the pebbles had been previously fractured by frost and thaw, as has been shown to be the case in the examples dealt with in this paper, the above conclusion seems to provide the necessary explanation for the presence of facetted and wind-worn pebbles in association with Drift deposits.

Summary

In this paper facetted and wind-worn pebbles are described from three localities near Manchester, and from three others in the Wirral peninsula ; in one case below the Lower Forest-bed of Cheshire.

The mode of occurrence shows the pebbles to be post-Glacial and pre-Neolithic in age. They have been acted on by sand-blast at some time after the deposition of the Glacial beds on which they lay, and in this respect they agree with similar pebbles found in North Germany and in North America.

A large number of the pebbles have been split or fractured before being acted upon by blowing sand, and it is suggested that the splitting is due to frost-action.

It is suggested that an intimate connection exists between the period of wind-erosion and the laying down of the Shirdley Hill Sand by aeolian action in early post-Glacial times. This sand usually rests on the Boulder-clay and is sometimes separated from it by a gravel-bed. The latter and the several deposits of facetted pebbles appear to occupy a somewhat analogous position with regard to the Drift to that of the basement bed, or "Steinsohle," of the Loess of the North German Plain, where facetted pebbles are of frequent occurrence.

The presence of the pebbles below the Lower Forest-bed of Cheshire is of importance as it pushes the period of wind-erosion well back in post-Glacial times, as the forest is prior to the estuarine deposits of the 25-foot submergence, and the latter are regarded as very early Neolithic.

It is concluded that the facetted pebbles do not furnish conclusive evidence of a dry climate or steppe conditions obtaining in this country in post-Glacial times.

EXPLANATION OF PLATES I. AND II.

Figs. 1 *to* 14. *Facetted and Wind-worn Pebbles. Pendleton, Lancs.* $\frac{2}{3}$*ths Nat. Size.*

PLATE I.

Fig. 1.—Coarse indurated ash with large quartz grains: upper surface showing two main facets, both of which show evidence of wind-erosion. The angle is probably due to erosion.

Fig. 2.—Very fine compact sandstone: the facet is a wind-worn split face; the splitting almost coincides with the lamination planes. The whole stone, including the under surface, shows signs of sand-blast. The angles are clearly due to fracture.

Fig. 3.—Very fine compact sandstone: upper surface showing two facets; one (the upper) is probably a split face smoothed by blowing sand, the other (lower) is the original surface of the pebble with the lamination planes slightly accentuated by wind-erosion. This pebble is also facetted on its under surface.

Fig. 4.—Very fine compact sandstone: upper surface showing three main facets; the lower facet faced N.W. when *in situ*. The left-hand facet coincides with the lamination planes. The under surface is water-worn. The typical "dreikanter" form is clearly due to fracture.

Fig. 5.—Very fine compact sandstone (bedding not perceptible): an irregularly facetted form. The under surface shows numerous glacial striæ in a longitudinal direction.

Fig. 6.—Very fine compact sandstone (bedding not perceptible): upper surface showing modified split face; remainder of stone is worn smooth by sand-blast. The angle is clearly due to fracture.

Fig. 7.—Fine gritty ash: upper surface showing five incipient facets and flat top, all differentiated. The under surface is quite flat and shows glacial striæ in various directions. There is no clear indication that this form has here been determined by splitting.

Fig. 8.—Very fine compact sandstone (Kirkby Moor Flag?): a typical "dreikanter," showing the relation of one of the three facets to natural planes of fracture due to recent frost-action by which the pebble has been broken. The fractured face (to left) would seem to have suffered considerable wind-erosion.

Fig. 9.—Fine compact sandstone: upper surface showing four facets and the picking out of bedding planes by wind-erosion. The facet to left coincides with the bedding planes. This pebble was found *in situ* in an inverted position.

Plate II.

Fig. 10.—" Rhyolite " : showing well-defined flow structure which has strongly influenced the form of the deep pitting due to wind-erosion. The under surface is not differentiated.

Fig. 11.—" Syenite " : typical " dreikanter," possibly wholly due to wind-erosion ; showing strong pitting. The under surface also shows erosion.

Fig. 12.—" Felsite " : the two facets of this pebble are extremely similar and deeply pitted, and both are probably due to wind-erosion. The under surface is flat and water-worn.

Fig. 13.—Exceedingly fine brecciated and veined sandstone, with the structure brought out in high relief by wind-erosion.

Fig. 14.—Porphyritic volcanic rock with abundant felspar phenocrysts : upper surface showing three facets, all deeply pitted and eroded. The pits on the two upper facets (at top in photo) are all elongated in a direction parallel with the ridge between these faces (vertical in photo) ; the pittings on the remaining face show no conspicuous elongation. The form of this pebble may, in some part, be due to fracture.

(All the above figured specimens, and a selection of others from the Wirral locality, have been deposited in the Manchester Museum.)

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X. Radio-activity and the Coloration of Minerals.

By Edgar Newbery, D.Sc., and Hartley Lupton, B.Sc.

(*Communicated by J. Wilfrid Jackson, F.G.S.*)

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The occurrence of the most varied and beautiful exotic colours in certain minerals is a feature whith attracts the attention of the most casual observer in a mineral museum.

Many attempts have been made to explain the source of these colours, but it is remarkable that no explanation so far offered has met with general acceptance. It is well known that certain inorganic or mineral substances acquire strong colours under the influence of the radiations from radium or in a cathode-ray tube, and the occurrence of radium or other radio-active bodies in the earth has been shown to be so widespread that it is difficult to obtain a sample of rock which does not show some traces of this activity.

The present work was undertaken, therefore, in order to determine, if possible, how far the presence of radio-active substances must be taken into account when trying to solve the question of the source of these exotic colours.

Previous Work.—So much work has been already done on this subject that it is impossible in a paper of this type to give more than the briefest outline of those papers which deal most directly with the same minerals as those used in the present work. Many statements have been made which apparently contradict each other, but which may both be true for the particular specimens used by each worker. It should therefore be emphasised that whilst the observations described here could be repeated with certainty as often as desired with the specimens used, other specimens apparently identical, and even from the same locality, may fail entirely to exhibit similar phenomena. An alphabetical list of references is given at the end of this paper.

Wyrouboff studied the colours of natural fluor-spar and came to the conclusion that they are due to the presence of two hydrocarbons, one producing blue and the other red colours. Assuming the former to be the more volatile, he explains the change from blue or violet to purple which is observed on moderately heating certain fluor-spars.

This explanation is untenable in the light of Berthelot's experiments, since certain decolourised fluors had their original colour completely restored by prolonged exposure to radium. If the

colouring matter had been driven off by heat, it is inconceivable that it should be brought back by radium treatment.

Barnes and Holroyd claim to have synthesised pure fluor-spar in crystals which showed all the known natural colours—green, yellow, rose, purple, etc. They therefore conclude that the colour is an optical phenomenon dependent upon the crystallisation and physical state of the substance.

The essentially weak point in Barnes' and Holroyd's theory is their statement that their "synthesised" fluor-spar was pure. It was made from calcium carbonate (presumably precipitated chalk, which usually contains traces of chloride, sulphate, sodium, water, etc.), and hydrofluoric acid. The latter, being always prepared from native fluor-spar, would contain most of the volatile impurities in the original fluor, together with other impurities picked up from the sulphuric acid used, the rubber bottle in which it was kept, etc. Finally the whole was heated in a steel tube to bright redness. Since the steel may contain carbon, hydrogen, sulphur, phosphorus, manganese, silicon, etc., in addition to iron, all of which may easily contaminate the fluor-spar, it is evident that the supposition that this fluor-spar was chemically pure is unjustifiable.

Strutt found that phosphatic nodules (coprolites) and phosphatised bones of all geological ages possess marked radio-activity, sometimes fifty times as great as that of the surrounding rock. He detected helium in these minerals even when they were not of more than Pleiocene age. He also detected and measured the quantity of helium in zircons, and from his results was able to calculate the minimum age of the rocks in which these were found.

Glew exposed kunzite, a pink transparent variety of spodumene, to the γ rays from radium for some days and found that the colour changed to green. On warming the crystal thus treated, a brilliant orange-coloured light was evolved for some minutes and the green colour was removed. He suggests that dissociation occurred under the action of the γ rays and that the subsequent heating gave the dissociated ions room to turn round and recombine with evolution of energy in the form of light.

Goldstein carried out a very interesting and extended investigation of the effects of cathode rays on certain colourless salts. Since cathode rays in a vacuum tube are of the same nature as the β rays from radium, it is quite possible that the effects obtained by Goldstein in a few seconds may be similar to those produced naturally in radio-active rocks in the course of centuries. Sodium chloride was coloured deep yellow; potassium chloride, violet; potassuim bromide, deep blue and sodium fluoride a fine red by a few seconds' exposure to cathode rays.

These colours are only produced on the surfaces exposed to the direct rays and are sensitive to light and heat in very different degrees. Some of the bodies thus treated emit a phosphorescent light when warmed. If salts such as sodium chloride are exposed to the cathode rays for considerable periods until they become quite hot, the colours produced are not discharged by light or gentle

heating, and if the salt is dissolved in water a strong alkaline reaction is obtained. Giesel produced similar salts by exposing the neutral salt to the vapours of sodium or potassium. It is evident therefore that, in this case, chlorine is actually liberated and the free sodium left dissolves in a deeper layer of sodium chloride unreached by the cathode rays.

Debierne found that certain dark violet fluor-spars smell of ozone. When heated they lose their colour and thermo-luminescence and also yield helium in variable but small quantity. On exposure to radium rays the violet colour was restored. Doelter has worked extensively on the question of the colour of minerals, and has investigated the effect of temperature changes, radium, and ultra-violet light. He states that increasing the quantity of radium used in colouring a crystal does not diminish the time in strict proportion, but he gives no reliable data in support of this statement. He also states that the quantity of radium used has no influence on the final colour produced. From slight differences in colour observed on treating certain minerals with radium in nitrogen and oxygen, he draws the doubtful conclusion that the radium rays exert a reducing action.

Ultra-violet rays were found in general to exert the opposite effect to radium rays, substances coloured by the latter being decolourised or the original colour restored by exposure to the light from an arc lamp. Glass and yellow diamond were found to be exceptions to this rule.

Doelter finally concludes that the colour of fluor-spar, topaz, rose quartz, etc., is due to the formation of colloidal metals or other colloidal substances, and that these metals oxidise when heated. He also states that the velocity of coloration is dependent upon *the diffusion of the radium into the material.* Since certain colours may be induced by the action of radium through two glass tubes and 0·5 cm. of lead, it is impossible to accept this last statement. Again, since strong colours may be induced 2 cms. deep in a clear solid fluor-spar crystal in a few hours by radium, and destroyed again in a few seconds by gentle heat, it is inconceivable that atmospheric oxygen can have any appreciable influence on the colour.

Experimental.—The minerals chosen for experiment were, as far as possible, clear crystals of bodies which either were colourless or were known to occur in a colourless state in nature.

The following properties were studied :—

i. Colour changes (*a*) on heating
(*b*) on treatment with radium or cathode rays
(*c*) on heating after treatment (*b*)

ii. Luminescence (*a*) under influence of rays
(*b*) on heating before treatment
(*c*) on heating after treatment.

Other minor effects, such as disruptive action, formation or enlargement of cleavage planes, etc., were also observed from time to time.

The following substances were experimented with :—

Elements.—Diamond, native sulphur.

Halides.—Fluor-spar, cryolite, rock salt, sylvine and artificial potassium bromide and iodide.

Oxides.—Quartz (including rose quartz, amethyst and cairngorm), ruby.

Sulphates.—Selenite, anhydrite, celestine, barytes, anglesite.

Phosphates.—Apatite, phosphorite.

Silicates.—Tourmaline, topaz, zircon, beryl, kunzite.

Carbonates.—Calcite, strontianite.

Other Substances.—Glass, bakelite.

Exposure to radium was made in most cases by placing a glass tube containing the radium salt directly on or very near to the specimen under observation. In this way only β and γ rays actually reached the crystal and of these only the γ rays would penetrate to any appreciable depth. This method of treatment is implied throughout the present work unless the contrary is directly stated. In many cases it was easy to distinguish the separate effects of the two types of rays, but in case of doubt, γ rays alone could be obtained by interposing a thin sheet of lead, or β rays alone by the use of a cathode-ray tube.

In a few cases the specimen was exposed to the direct influence of the emanation by putting it into a tube containing the active gas over mercury. In this case α, β and γ rays would act simultaneously.

Diamond.—This was a small pale yellow crystal from New South Wales kindly lent to us by Prof. Boyd Dawkins. No change of colour and no luminescence was observed on heating to redness in a soft glass tube.

When exposed to radium the specimen glowed with a bright blue light, while an imitation diamond placed alongside it was quite inactive.

Exposure to 4 mg. of radium for twenty days had very little visible effect upon this crystal. The colour appeared very slightly deeper, but was restored to its original condition without luminescence on gentle heating.

Exposure to 20 millicuries of emanation decaying over a period of seven days in contact with the crystal produced a more marked darkening of the yellow colour.

Crookes, by embedding a Bingara yellow diamond in radium bromide for seventy-eight days obtained a bluish-green colour.

Sulphur.—A clear crystal of native sulphur from Vesuvius was exposed for twenty days to 50 mg. of radium. No change of any kind could be detected and no luminescence was produced. Doelter states that sulphur is slightly changed in colour.

Fluor-spar.—Owing to their wonderful range of colour and the remarkable thermo-luminescence of many specimens, the fluor-spars are undoubtedly the most interesting minerals dealt with in this work. In fact, a comparison of the very similar behaviour on heating of purple fluor and of glass which had been turned purple by radium was the initial observation which led to this research.

A number of different specimens were used, including violet, purple,[1] green and yellow crystals from Alston Moor, Cumberland; a colourless specimen from the same locality; a pale green chlorophane from Cornwall; a colourless specimen from the Pyrenees, and another from Matlock.

All the coloured specimens without exception lost their colour on heating, but the time and temperature necessary to completely discharge the colour varied considerably. The green specimens were the most difficult to decolourise completely, a dull red heat being necessary for fully five minutes. The colours artificially induced by the action of radium were much more readily discharged, warming to a temperature not much above 100° C. being sufficient in many cases.

Thermo-luminescence was very marked in all the naturally coloured crystals, a violet light being emitted in most cases, frequently strong enough to read by at a distance of six inches. Decrepitation was generally violent, except with the pale purple crystals, but no naturally coloured crystal was found which could be heated without some decrepitation. The yellow and dark violet varieties were most violent.

Of the colourless varieties, that from the Pyrenees gave an almost invisible glow when very strongly heated, while that from Matlock gave no light at all. Neither of these showed any tendency to decrepitate. The Alston Moor colourless specimen on the contrary gave a very lively display of decrepitation and also of beautiful violet light. The Cornish chlorophane also decrepitated violently, but gave a beautiful green light instead of the violet light given by the other coloured specimens.

All the fluor-spars showed a green glow when under the action of radium, and a violet glow in the cathode rays. The glow continues in each case for a short time after removal of the exciting source.

The colour changes produced by radium on fluor-spars are so varied as to be somewhat bewildering.

A green crystal heated until all the colour was discharged and then given an exposure of two days to 25 mg. of radium showed a marked green colour. On further exposing for four days, this green colour was strengthened up to its original depth, and still longer exposure did not alter this. This result seems to indicate that the colour-producing substance in the green crystals, whatever that may be, is limited in quantity.

A yellow crystal treated in the same way did not recover its original colour but acquired a peculiar shade of blue, which slowly changed to purple after two months without further treatment.

[1] The distinction between violet and purple appears to be only one of degree and not of actual colour. A small violet crystal appears of the same colour as a large purple one when viewed by transmitted light. Many of the violet or purple crystals are only coloured on the surface or on thin plates or zones within the crystal, the main bulk of the crystal being nearly colourless. This zoning of the colour needs careful inspection to detect and is easily overlooked.

A purple crystal also failed at first to regain its original colour under the action of radium but acquired the same peculiar blue, which again changed to purple in a similar manner.

The colourless Alston Moor specimen showed traces of a lighter blue colour after twenty days' treatment with 25 mg. of radium, but immediately under the radium tube the crystal was broken up and a yellow stain produced. This yellow colour slowly penetrated the whole crystal on further treatment.

The colourless Pyrenean specimen was uncoloured by the radium treatment given to it, but it rapidly acquired a deep purple colour with a brilliant bronze surface tarnish under the action of the cathode rays.

The most striking colour effect in this work was obtained with the colourless Matlock fluor. After only twenty-four hours under 50 mg. of radium, the whole crystal attained a wonderful deep blue colour, resembling, but deeper than, that of a copper sulphate crystal. This particular type of colour is very rare, if it occurs at all, in any natural fluor. It is quite permanent if the crystal is kept in the dark, but is rapidly destroyed (in about three hours) in direct sunlight, more slowly by diffused daylight. It is also destroyed by gentle heating, but may be restored as often as desired by renewed radium treatment. Strange to say, this species of fluor is difficult to colour by cathode rays, which only produce a faint purple on the surface. It appears therefore that the purple colour of fluor-spar may be produced by β radiation, while this blue colour, which is similar to though stronger than that produced in the decolourised yellow and purple crystals, is due to the action of γ rays. The green, yellow and blue colours were produced right through the crystals, while the purple was never more than 1 mm. deep. No colour other than purple was given to any of these fluors by cathode rays.

The thermo-luminescent effect after treatment with radium was very striking.

The coloured varieties, on strongly heating, completely lost their power of emitting light. After treatment with radium this power was restored, but in addition a new capacity for emitting a bright green light at a comparatively low temperature was imparted to all the specimens whether previously heated or not. The quantity of light emitted varied with the time of exposure to radium and also in different specimens. The Matlock fluor, after colouring blue with radium, gave a comparatively feeble green light on heating and this light soon faded without changing colour. The Pyrenean specimen, which was quite uncoloured by long exposure to radium, gave a wonderfully brilliant and lasting green light. Some pieces left on the table 6 in. away from the radium were nearly as brilliant as the fully treated specimens, although none showed more than an extremely faint glow before thus treating. This shows conclusively that the γ rays are responsible for generating this green thermo-luminescence.

All the other specimens after treatment with radium gave at

first a green light on slightly heating. This reached a maximum, and then died down, but before it disappeared a new violet glow started which also reached a maximum and died down on further heating, after which no light was emitted as the crystal was heated to dull redness.

The Cornish chlorophane, which gave a brilliant green phosphorescence, had evidently been in close proximity to radio-active matter giving γ rays. This is quite in keeping with the known occurrence of pitchblende and other uranium minerals in Cornwall.

Cryolite.—A white semi-transparent specimen from Canada was quite unchanged after prolonged exposure to radium, but acquired a slight thermo-luminescence.

Rock Salt, Sylvine, Potassium Bromide and Iodide.—All these alkali halides glowed with a bluish violet light under the action of radium.

Rock salt is coloured brown throughout its mass, but more strongly nearest the surface exposed to the radium and on cleavage planes further in the crystal. In a cathode-ray tube a similar brown colour is produced on the surface only.

Sylvine is coloured blue by radium, but the colour is very evanescent and disappears after a few hours even when kept in the dark. In a cathode-ray tube it is coloured deep violet, and chemically pure potassium chloride acquires the same colour, which is much more stable than that produced by radium.

Potassium bromide is coloured sea-green by radium, or cathode rays, the colour being nearly as evanescent as that of sylvine when produced by radium, but more stable when produced by cathode rays. The time necessary to colour this specimen was much longer than that for potassium chloride.

Potassium iodide is coloured brown like sodium chloride, but the colour is much more stable than that produced in any of the other alkali halides. It was thought that the colour in this case might be due to the liberation of iodine, but when a small crystal which had been coloured deep brown was dissolved in water no trace of iodine could be detected by the starch reaction.

None of the above group showed more than an extremely faint thermo-luminescence after radium treatment.

Quartz.—This mineral shows a still greater variety of colour than fluor-spar, but only a few of these varieties occur clear and transparent. The best-known are rock crystal, rose quartz, amethyst, cairngorm and citrine, all of which become colourless on heating. The temperature necessary to destroy the colour varies greatly—rose quartz requires a red heat, amethyst requires strong direct heating in a blow-pipe flame, while nearly black cairngorm may sometimes be made quite colourless and limpid by heating in a soft glass tube.

Prof. Rutherford found that radium exerts a powerful disintegrating action on transparent *fused* quartz, a tube of this material becoming so rotten that it fell to pieces on being touched after being left in contact with radium for a few weeks. No sign of this

" rotting " action was observed with the crystalline specimens used in the present work, so that this appears to be a property of fused quartz only.

With all the specimens the action was very slow. A clear limpid crystal on treatment with 25 mg. of radium for seven days became smoky, the colour being strongest at the spot where the radium tube was in contact with the crystal, but penetrating to a depth of 1 cm. into the crystal.

Rose quartz after decolourising by heat also became smoky, but rather more readily than the rock crystal. The pink colour was also restored to a slight degree. Amethyst decolourised by heat showed little or no smokiness on treatment with radium, but the clear purple colour was slowly restored.

A nearly black cairngorm, which was easily rendered clear and colourless by heat, slowly regained its colour under the action of radium, the change being rather more rapid than with any of the other quartz specimens.

All the crystals thus recoloured were readily decolourised by moderate heat, and in all cases a very faint thermo-luminescence was observed.

Ruby.—A small light-coloured fragment from Carolina on heating strongly appeared green, but regained its original colour on cooling. Treatment with 25 mg. of radium for ten days had no appreciable effect on the colour, but a slight thermo-luminescence was produced which rapidly disappeared on further heating. Otherwise, no change was observed. In view of the fact that artificial rubies, indistinguishable from natural ones, can be made by fusing pure alumina with a trace of chromium, the unchangeability of the colour by radium is not surprising, the colour being intrinsic and not exotic.

Selenite.—A number of clear and perfect crystals from the Kimmeridge clay were used. These decompose with loss of water of crystallisation at a comparatively low temperature, so that no thermo-luminescence could be observed.

After the application of 50 mg. of radium for two days, a peculiar effect was observed in the crystal. On looking through the two large faces of the crystal at a white object, these faces appeared to be divided into four triangles by diagonals of the parallelograms. The two triangles having as bases the longer sides of the parallelogram were coloured a faint smoky brown, while the other two were unaltered. Further exposure to 25 mg. of radium for fourteen days darkened the coloured parts slightly, but left the remainder of the crystal still unchanged. Several crystals were tried and fresh clear faces prepared by cleaving off thin sections; also the direction of the radium tube relative to the crystals was changed, but the same result was obtained in every case. The explanation of this peculiarity is due to Sir Henry Miers.

When the crystal was in its initial stages of growth, its faces were similar, and similarly situated, to those of the fully developed crystal. Certain of these faces have different properties from other

faces, and by reason of these properties (probably electrical) were able to attract certain impurities which had no effect upon the colour of the crystal before the radium treatment was applied. As the crystal grew, therefore, the path of growth of these faces was traced out by the presence of the impurities, and the impurities were then made visible by the action of the γ rays from the radium.

Anhydrite, Celestine and Barytes.—These anhydrous sulphates of the alkaline earths all occur in the state of clear glassy crystals, which are sometimes colourless and sometimes blue. Celestine in fact owes its name to the sky-blue colour of many specimens.

Since this blue colour can usually be discharged by heat, it was expected that colourless specimens would, in some cases at least, be coloured blue by radium. This expectation was fulfilled with all three minerals, but to different degrees. Anhydrite in clear crystals is rare, and the only specimen the authors were able to get required six days under the action of 30 mg. of radium before any decided blue colour was obtained. The crystal emitted a green glow during exposure to the radium, and was slightly phosphorescent afterwards when heated gently.

Celestine treated in the same way was coloured pale blue more readily than the anhydrite, but further treatment did not increase the colour appreciably.

One specimen of barytes showed no colour after similar treatment, but a large clear crystal from Cumberland was coloured a fine deep indigo blue after nine days under the action of 25 mg. of radium. The blue colour was fairly uniform throughout the whole crystal and it is therefore probably due to the action of the γ rays alone.

This conclusion is rendered more probable by the fact that a similar crystal of barytes was unchanged under the action of cathode rays. The fact that certain specimens of barytes and celestine are uncoloured, or hard to colour, by radium indicates that the blue colour is due to changes in some impurity and not to dissociated particles of the pure substance.

Anglesite was chosen for experiment as being the only available colourless crystalline anhydrous sulphate which could be compared with those of the alkaline earths.

The action of radium was very slight. After twelve days under 30 mg. of radium a barely visible blue colour was produced.

The action of cathode rays on this mineral is peculiar. When the tube is exhausted until cathode rays just begin to appear the crystal emits a bright blue glow, while a fluor-spar crystal by the side of it is hardly affected. As exhaustion proceeds and the rays become harder, the fluor rapidly increases in brightness, but the anglesite glow diminishes until it is barely visible under very hard rays. No other crystal used in this work showed this peculiarity.

Apatite and Phosphorite.—These two minerals, though having identical chemical composition, show considerable differences under the action of radium.

Several specimens were used, including brown and green crystals

from Canada, a very hard phosphorite from France, and a mixed apatite and phosphorite from Aqua del Todo Año, Spain. This last specimen contained zones of a beautiful mauve apatite separated and surrounded by a white flaky phosphorite, and provided the most brilliant example of thermo-luminescence observed throughout this work.

All the specimens used approached the colourless state on heating. The Canadian specimens became pale brown and very pale blue respectively on heating small pieces on a platinum wire before a good blow-pipe, while the mauve Spanish variety became pure white on warming in a soft glass tube. The green Canadian variety was also rendered white by long heating, but the brown specimen still retained much of its colour. All the apatite specimens gave a feeble phosphorescence on heating strongly in a hard glass tube. The French phosphorite decrepitated but gave no visible light. The Spanish phosphorite on gentle warming appears to take fire and a beautiful golden yellow glow is emitted, so brilliant that a fragment the size of a small pea allowed the time to be easily seen on a small watch held a foot away. This glow only lasts for about thirty seconds to one minute and then disappears, after which, further heating has no effect.

No colour change was produced by the action of radium on any of the original untreated specimens, but the thermo-luminescence was increased in all cases.

The green Canadian apatite, which had been turned white and semi-transparent by strong heating, was coloured a fairly strong brown by two days' exposure to 50 mg. of radium. When this brown substance was gently heated in a soft glass tube a brilliant violet light was emitted many times stronger than that obtained with the unheated specimen. The brown colour faded rapidly in daylight.

The brown Canadian apatite behaved similarly to the green variety, although the colour change on treatment with radium was hardly visible.

The French phosphorite after treatment with radium was unaltered in appearance, but the thermo-luminescence was strong, and violet in colour.

The Spanish phosphorite, after heating until all the glow had disappeared, was treated with 25 mg. of radium for six days. No change in external appearance was produced, but on heating it was found that the power of emitting the beautiful yellow light had been restored, and was greater and more lasting than that of the original specimen.

The finest display of this yellow light was however obtained when a large fragment of the original material was brought under the action of the cathode rays. In this case there is no disappearance of the glow with time ; it continues with undiminished brilliancy as long as the rays fall on the substance. Also, a specimen which had been deprived of its thermo-luminescence by strong heating regained this property with increased brilliancy in the cathode rays.

Tourmaline.—Though this is quite a common mineral, yet clear crystals are rare, and generally valuable, especially the lighter coloured ones. Three specimens were used, a dark green semi-transparent crystal from Cornwall, a pink crystal (rubellite) from Canada, and a small colourless specimen from Elba.

The green specimen became darker and more opaque on heating, and no visible effect was produced by radium on the heated or unheated specimens.

The pink crystal turned quite white and opaque on heating before the blow-pipe. Radium produced little visible effect on the original specimen (slight darkening of the pink colour), and none at all on the heated specimen. Cathode rays produced no colour effect on either, but the heated specimen showed a very fine orange glow, whilst the unheated crystal was unaffected.

The colourless specimen showed a faint pink colour after one day under 50 mg. of radium, and this was considerably strengthened after four days' further treatment. Its colour then showed considerable resemblance to that of the Canadian rubellite, and five days' further treatment with radium did not change this. The limit of colour for this specimen had thus apparently been reached.

Topaz.—Transparent crystals of topaz are common, and are found colourless, yellow, pink and blue, but are usually intersected with large numbers of flaws.

Yellow topaz from Brazil changes to a purplish pink on strongly heating, while similarly coloured specimens from Aberystwith become almost colourless.

None of these exhibit any thermo-luminescence before, and very little after, radium treatment. A clear colourless crystal from the Mourne Mountains acquired a fine deep yellow colour after four days under the action of 10 mg. of radium.

A yellow crystal from Brazil became slightly deeper coloured after similar treatment.

A similar crystal, heated until it turned pink, and then treated with radium, regained its original colour and then became slightly deeper coloured than the unheated specimen. On reheating, the crystal again became pink, with slight thermo-luminescence.

Zircon.—Clear crystals occur as hyacinth (pink to deep red) and jargoon (colourless).

Specimens of hyacinth from Tasmania and from the centre of France were used. These varied greatly in their behaviour on heating. Some of the Tasmanian specimens became nearly colourless when heated in a hard glass tube and quite colourless and transparent when heated on platinum wire in a bunsen flame. On the other hand, some of the French specimens still retained a pale yellow colour after five minutes' heating in a good blow-pipe flame.

All the specimens, heated or unheated, showed a greenish glow when exposed to radium. The unheated ones were unchanged in colour, but the heated ones all regained their colour to a greater or less extent.

The colour of those Tasmanian specimens which had been

most easily decolourised was completely restored after only two days under 25 mg. of radium, while some of the French specimens which had been most difficult to decolourise were not visibly affected by this treatment, and only regained about half their colour after treatment with 50 mg. for ten days.

One of the most refractory of these decolourised crystals was placed in a tube containing about 20 millicuries of radium emanation and left for twelve days. It had then acquired a reddish grey colour with a peculiar blue fluorescence somewhat similar to that of purple fluor-spar. On warming gently in a test-tube, a bright violet phosphorescent light was emitted and the crystal at once lost its blue fluorescent colour and turned red, the colour being now similar to that originally present. This colour was easily destroyed on further heating. Similarly all the crystals which had been re-coloured by radium, lost their colour at a much lower temperature than had been needed to discharge it before treatment.

A decolourised crystal placed in a cathode-ray tube glowed with a blue light and regained part of its red colour.

Beryl.—The natural crystals show considerable variation in colour, from white or colourless, through pale blue (aquamarine) and pale green to the bright green of the precious emerald. Specimens of colourless, pale blue, and pale green beryl were used. The green specimens, from the Mourne Mountains, changed to pale blue on heating in the bunsen flame, while the other specimens were unaltered.

No change in colour was produced in any of the crystals by radium treatment, but a pale blue crystal, 1 cm. long and about 3 mm. diameter, after treatment for ten days with 25 mg. radium, showed a feeble thermo-luminescence. This luminescence was bluish white and appeared on the hexagonal basal planes only, the remainder of the crystal being quite dark.

Kunzite.—The behaviour was identical with that described by Glew.

Calcite.—Several colourless specimens from Barrow and Iceland were used, some showing minute cleavage planes and others quite flawless. The latter were unchanged by the action of radium but the former showed considerable multiplication and enlargement of the cleavage planes.

A very clear flawless crystal glowed with a fine red light under the action of cathode rays, and the glow continued for some time after removal of the crystal from the tube.

Another specimen from Iceland also glowed both in cathode rays and under radium, but with a much whiter light. In the latter case the warmth of the hand was sufficient to restart the glow after removal from the radium. A third specimen showed a bright yellow thermo-luminescence after radium treatment.

The variation in colour of the glow appears to indicate that it is due to the presence of impurity and is not an essential property of the pure substance. A piece of native strontianite showed a fine orange-red glow on one part of the mass under the action of

cathode rays, while the other part remained unaltered. This again indicates that the glow is due to impurity present in the crude mineral. On heating the specimen thus treated, a bluish white glow was observed on the previously inactive part of the mass, while the remainder was quite dark.

Glass.—The action of radium on glass is well known. Soda-glass is coloured violet by the prolonged action of radium, and when this glass is heated a pale violet light is emitted and the colour is discharged. In this respect its behaviour is very similar to that of purple fluor-spar, but the thermo-luminescence is not so bright. Some samples of treated soda-glass require heating to the softening point before all the colour is discharged.

Jackson considers that the green phosphorescence of X-ray tubes depends upon the presence of traces of manganese. Without this the glow is faint blue.

Lead glass acquires a fine brown colour under the action of radium, and this colour is also discharged by heat. Boro-silicate glass acquires a purplish brown colour. Other coloured glasses are described by Doelter.

Bakelite, a hard resinous condensation product of certain aldehydes and amines, is amber-yellow when freshly made, but gradually acquires a wine-red colour under the action of daylight. If the red colour is not too strong it may be discharged by heating to 100-150° C. for several hours. One sample tested by the authors was restored to its original yellow colour by twelve hours' heating to 130° C. in an air oven, whilst another more deeply coloured specimen was only slightly affected by three days' heating to 150° C. Radium or cathode rays produce an effect similar to that of daylight, but the colour thus produced is much more easily discharged on heating.

This colour change of bakelite has proved objectionable when the substance has been used for ornamental purposes (imitation amber) and has led to its abandonment in certain trades.

Summary and Conclusions.—There appears to be little doubt that the colours and thermo-luminescent properties of many minerals have been largely determined by the presence of radio-active matter either in the water from which they have been deposited or by the subsequent action of radio-active minerals in their immediate neighbourhood. It appears possible, though not proved, that fluorescence is produced by α radiation as in the case of zircons. Different colours may be produced by β and γ radiation and all three effects may be observed in one and the same crystal (*e.g.* the fluorescent purplish green fluor where the green colour is restored by γ rays, the purple by β rays, and the complete colour by placing in a tube of emanation where α, β, and γ rays act together).

Both β and γ radiation appear to be active in producing thermo-luminescence.

In nearly all cases the colours produced are due to the dissociation of minute traces of certain impurities. The products of dissociation are removed to a very short distance from each other,

and the size or density of these particles will determine the particular colours of light absorbed and transmitted.

Disturbance of the molecular structure of the crystal by heat, daylight, etc., enables the dissociated particles to approach each other and recombine, with consequent loss of colour.

The quantity of impurity may be exceedingly small, since the dissociated body appears to act as a powerful dye, and in many cases it may be impossible to determine its chemical nature largely owing to the difficulty of obtaining a perfectly pure sample of the original substance.

The question as to whether a perfectly pure substance is capable of showing these colours is still open to doubt, although Goldstein's work seems to point to the conclusion that such is possible. With potassium chloride Goldstein obtained a deep violet coloration in cathode rays, and the authors of this work had no difficulty in repeating the experiment. With potassium bromide, Goldstein obtained a deep blue coloration, while the authors obtained a green colour; also this sample required twenty minutes' treatment before any appreciable colour was obtained, while Goldstein's colour was obtained in a few seconds. It seems still possible therefore that the colours may be due to traces of impurity, which are always present in the purest obtainable samples. Goldstein estimates that certain impurities, amounting to not more than one part in a million, may produce quite perceptible colour effects under the influence of cathode rays. He has also shown that the same impurity may give rise to different colours when present in different solids, a fact which well illustrates the danger of attempting to utilise the colour as a guide to the nature of the impurity in minerals.

At first sight, the production of the Giesel salts by heating pure salts in sodium or potassium vapour, having the same colour as those produced by cathode rays, would seem to be indisputable evidence that the colour is due to metallic potassium or sodium. When the intensity of the colour is considered, however, the evidence appears much less satisfactory. If a trace of metallic potassium, so minute that its presence is beyond detection by chemical means, is sufficient to colour a large mass of potassium chloride dark violet, then the quantity present in Giesel salts should render them so black that the colour is indistinguishable. This is not the case. It is quite possible therefore that metallic potassium, introduced either from outside or from within by the action of cathode rays, is only a reagent which causes the dissociation of the colouring material whatever that may be, and is not really the colouring agent itself. This theory would explain why long-continued action of the cathode rays never carries the depth of colour beyond a certain limit, although the quantity of free metal is steadily increasing all the time. It also explains why those colours which Goldstein terms "after colours of the first class" should be identical in appearance with "after colours of the second class."

The emission of light on heating the radiated crystals is probably due to intense vibrations set up by the dissociated atoms

coming together again. The impurities which give rise to this luminescence are frequently quite independent of those which produce the colour effects, since quite colourless crystals sometimes give brilliant thermo-luminescent effects, and deeply coloured crystals may give little or no visible luminescence during discharge of their colour. It is also possible that the approach of the separated particles due to electrical attracting forces may set up light-producing vibrations as successive obstacles in their paths are encountered or passed, while the colour disappears with the final coalescence of these particles.

It appears to be fairly well established that phosphorescence cannot be produced in a perfectly pure substance. The most brilliant phosphorescent effects are produced in substances such as calcium sulphide by minute quantities of compounds of bismuth, mercury, etc., and this effect is quite destroyed either by largely increasing the impurity or by removing it altogether.

The authors are of opinion therefore that thermo-luminescence, cathode-ray colours, exotic colours in minerals, etc., are due to the dissociation of traces of impurity in the bodies concerned and not to decomposition of the body itself.

The marked differences in the action of β and γ rays in producing different colours, thermo-luminescence, etc., in certain minerals seems to indicate some essential difference in the nature of these rays other than mere wave-length.

The radium used in these experiments was the property of the Manchester and District Radium Committee, and to them the authors are indebted for permission to use it. In conclusion, the authors wish to express their thanks to Sir E. Rutherford, Mr. C. J. Woodward, of Birmingham, and Mr. T. H. Hill, of Manchester, for several of the specimens used, and specially to Mr. J. W. Jackson, of the Manchester Museum, for many specimens and for his continued interest and encouragement in this work.

Most of the specimens referred to have been deposited in the Manchester Museum, and may be seen on application to Mr. J. W. Jackson.

Electro-Chemical Laboratories,
Manchester University.

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XI. The Superficial Geology of Manchester.

By Margaret Colley March, M.Sc.
(*Geological Department, The University, Manchester.*)

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While much has been written concerning isolated exposures of the Glacial and alluvial deposits in and around Manchester, no general account of them has been attempted since the early descriptions by the late Mr. E. W. Binney and Mr. Hull. A precise knowledge of these surface deposits is of exceptional importance in a great city, in connection with building, municipal and general engineering operations, and questions of water supply and drainage. The opportunity has therefore been taken, in connection with a general investigation of the geology of the district for coal-mining purposes, to collect all the data available concerning the superficial deposits and to give a general account of them.

The present account is based on an examination of all the published evidence (see Bibliography) supplemented by many sections of cuttings and bore-holes kindly supplied by the Manchester City Surveyor, together with large numbers of well sections supplied by Messrs. Mather & Platt, Mr. Charles Chapman and Mr. A. Timmins; by information supplied by the Chief Engineer of the Manchester Ship Canal, and by field observation. Mr. J. W. Jackson, of the Manchester Museum, has also contributed his personal records and allowed the use of observations left in manuscript by the late Mr. Charles Roeder.

In the latter portion of the paper some discussion will be given of the relation of the Drift deposits to the present surface configuration of Manchester, and of the form of the pre-Glacial surface.

The distribution of the Drift in the Manchester area was first worked out by Mr. E. W. Binney, who published a description, illustrated by a map of the district, in the *Memoirs* of this Society in 1848. Since his time a great deal of the Drift formerly exposed has been covered up, but, on the other hand, numerous fresh borings and sewer sections have been made in it, disclosing its vertical and horizontal distribution. The new evidence does not appear to require any great modification of Binney's map other than a rather wider extension of the river gravels than he allowed.

The superficial deposits are of three kinds, each of which occupies a distinct area:

1. *River Gravels.*—These deposits vary considerably. They include true river gravels and sands, consisting mainly of re-sorted Drift materials, which are often difficult to distinguish from true Glacial

deposits when they occur at high levels; loam and peat also come under this category. These deposits are, of course, post-Glacial.

The low-lying area of the south-west of Manchester is almost entirely underlain by these deposits, which are spread on either side of the River Irwell and its tributaries, the Cornbrook, Medlock and Irk.

From this area the gravels extend up the valleys as follows :—

On the south side of the River Irwell itself, below the confluence of the Cornbrook, the gravels extend as far as the Stretford Gas Works, while to the south of the Cornbrook they reach a little way beyond Alexandra Road. In the Chorlton district the gravels stretch a little to the east of the point where Platt Brook joins the Cornbrook.

Hulme, lying between the Cornbrook, the Medlock and the Irwell, is entirely on river gravels and sands. Farther north, the gravels cover the angle between the Medlock and the Irwell, and reach as far as the south-west corner of Central Station, and the junction of Minshull Street and Whitworth Street. Above this the gravels lie only very close to the Medlock itself.

On the north side of the Irwell, below the confluence of the Medlock, the gravels underlie the area now occupied by the Ship Canal docks, while on the same side of the river, below the junction of the Irk, they occupy a comparatively narrow belt.

Between the points where the Irk and Medlock join the Irwell the gravels continue to Deansgate, where they gradually thin out, being replaced by Boulder-clay at Central Station, at the corner of South Street and Peter Street and in Albert Square.

In the Irk valley itself river deposits occupy a narrow belt on either side the stream.

Above the junction of the Irk and Irwell, on the right side of the Irwell, river gravels occur in Cheltenham Street, Pendleton and in Cobden Street.

On the left side of the river there are alluvial deposits in Sussex Street, Broughton, and in Grœcian Street, Broughton, while, according to Binney, they occupy the whole tract encircled by the loop of the Irwell.

2. *Boulder-clay.*—The Boulder-clay of the Manchester district is entirely of the North-Western Drift type—that is to say, the boulders contained in it are mainly from the Lake district, and apparently it contains none of the limestone blocks which characterise the Ribblesdale Drift. The boulders themselves are often of enormous size, as, for example, the one which was obtained from Oxford Road, and is now placed in the quadrangle of the University.

The Boulder-clay covers South Manchester in areas where it is not replaced or overlain by river deposits. In Salford and the south of Pendleton it covers the ground except in the river valleys. In Clayton and Newton Heath, Beswick and Bradford it forms the only covering, and in North Manchester it occurs to the east of Rochdale Road.

3. *The Glacial Sands.*—The sands often attain great thickness.

They show marked current bedding, and contain thick pockets of clay, and thin streaks of coal fragments. In places they are slightly faulted. They vary in texture from fine running sands to gravelly deposits.

These sands cover the north of Manchester from Boggart Hole Clough in the east to Prestwich in the west, and are continued across the Irwell over North Pendleton and Irlams towards Eccles.

The horizontal distribution of the post-Glacial and Glacial deposits as shown by recent information, therefore, agrees with Binney's map, except that the extension of the river deposits in the Stretford area has now been shown to be greater than was there indicated.

The Vertical Sequence of the Drift Deposits

There is considerably more information concerning the vertical sequence of the Drift than was available when Binney and Hull discussed the subject.

In the Manchester area all the bore-holes and cuttings south of a line from Newton Heath to Pendleton show that the Glacial deposits, where they have not been eroded by the rivers, consist almost entirely of Boulder-clay. In the south and north of this area sandy bands of considerable thickness are found to occur within the clays. These bands, however, are all lenticular and inconstant, as shown by the following examples.

In the Fallowfield district the sewer laid along the Wilmslow Road shows great variability of superficial deposits. This is clearly seen in the section (Fig. 1, Pl. III.). Between Ladybarn Road and Monmouth Street there is a sand-bed which at Ladybarn Road is 11 feet thick, at Old Hall Lane more than 27 feet thick, and at Monmouth Street 9 feet in thickness.

In the northern part of the Boulder-clay district a bore-hole put down by the Clayton Aniline Company shows clay with sandy bands. Roeder gives a section of a sand-pit in this vicinity, behind Clayton Hall. The record is incomplete, as the only mention is of a 7-foot sand-bed. In the 6-inch Ordnance Survey map published in 1847 two sand-pits are marked in this district; one near the Ashton New Road end of Schofield Street, about 200 yards from the site of the present brick works, and the other about 100 yards north of Alderdale House, and the same distance east of Edge Lane.

In a bore-hole at the Pott Street Hydraulic Power Station 80 feet of Boulder-clay with "sandy bands" was proved.

In the Newton Heath area the deposits are very variable, some showing clay only, others clay with sandy bands, while the bore-hole at Newton Heath Brewery has a 30-foot sand-bed, 19 feet from the bottom of the Drift, and that of the Heath Brewery proved 25 feet of quicksand, 50 feet from the base of the Drift.

Farther to the east, in Jericho Clough, Clayton Bridge, a bore-hole recorded by Binney shows two sand-beds, the thicker being 12 feet.

North of Newton Heath, along the Rochdale Road, a set of sewer sections show that there is Boulder-clay overlying a sand-bed. The rock below this sand-bed is not reached until the sewer is opposite the Manchester General Cemetery. Here the sand-bed is reduced to 7 feet in thickness and lies between Boulder-clay and the solid rock (Section, Fig. 2, Pl. III.). To the east of the man-hole by the corner of Westbourne Grove, in Rochdale Road, five sections are known, the last being in the Moston Collieries. The first two are sewer sections and show clay on sand; the first proves 73 feet of sand under 82 feet 6 inches of clay, the second 30 feet of sand under 44 feet of clay. In neither case was the base of the Drift reached. The next section is the well sinking in the old Crumpsall Workhouse, 150 yards from the second man-hole; this section reaches rock, and shows, in descending order: clay, 5 feet; sand, 42 feet; clay, 58½ feet; gravel, 9½ feet; rock. The next sinking is a man-hole about 450 yards east of the workhouse, which proves a sand-bed 24 feet thick, with 71½ feet of clay above and another clay below. The solid rock is not reached.

From the Moston Collieries, about three-quarters of a mile farther east, there are two shaft sections which give details of the Drift. One of these is the No. 3 Shaft of the present colliery, the other is Moston Old Shaft, recorded by Binney in 1870 as Moston "New" Pit Section. Both these shafts agree in having a gravel bed at the base, but above this they show considerable variation. Moston Old Pit has three sand-beds, the top one being 5 feet 9 inches thick, the middle one 14 feet thick and the bottom one being 15 feet in thickness. Moston No. 3 Pit has one sand-bed only and that is 30 feet 7 inches in thickness and underlies 36 feet of clay.

Between the Moston Collieries and Rochdale Road lies Boggart Hole Clough, which is about 600 yards north of the old Crumpsall Workhouse. In this clough the solid rock cannot be seen, the sides of the ravine showing nothing but glacial sands. Near the top there is a band of sandy clay about 5 feet in thickness. This sandy clay is unfit for brick-making.

East of Rochdale Road deposits similar to those of Boggart Hole Clough are to be seen stretching from above Blackley, westward across Kersall Moor and southward to Alms Hill. Here, as in Boggart Hole Clough, the superficial deposits are Glacial sands without any covering of Boulder-clay. Near the top of these sands there are occasional lenticular bands of sandy clay which hold up the water. In places they have been cut through, and in these cuttings they can be seen dying away in all directions. In none do they attain a thickness of more than 10 to 15 feet.

Although the base of the sands cannot be seen on Kersall Moor or in Boggart Hole Clough, it is visible in the Irwell valley opposite to Agecroft Bridge, and has been proved in the bore-holes at Messrs. Levinstein's Crumpsall Vale Dye Works, and on the eastern edge of the lake in Heaton Park. In the Irwell valley and the bore-hole at Messrs. Levinstein's the sand comes down on to the solid rock without any intervening clay, but at Heaton Park there are 33 feet of clay between the sands and the rock.

The evidence from the sections quoted above, and from numerous others, proves that there is great variability in the Glacial deposits of the Manchester district. In places these deposits consist mainly of thick clays or equally thick sands, but the clays may contain lenticular sandy bands, and the sands lenticular clay bands.

It is very desirable to consider the vertical sequence of the Drift deposit in the Manchester area with reference to the classifications proposed for them, in view of the important theoretical and practical deductions which have been drawn from their supposed arrangement.

Classification of the Glacial Deposits

The first of these classifications was proposed by Binney in a paper which he read to this Society in 1848. In this paper he gave the vertical succession as being—

*(4) River gravels.
(3) Glacial sands.
(2) Boulder-clay.
(1) Gravel-bed.

He himself, in referring to his classfication, says: "Probably the deposits mentioned above will not always be found in the perfect order there laid down; no doubt some of them may be found wanting at places; especially the Glacial sands and the gravel-bed, which have often been removed." In the many sections now available the gravel-bed is absent nearly as often as it is present, so that it does not seem desirable to regard it as a definite stratum.

The second classification was proposed by Hull in 1863 and was by no means tentative, as Binney's was. It is as follows :—

(3) Upper Boulder-clay.
(2) Middle sands and gravels.
(1) Lower Boulder-clay.

This tri-partite division of the Drift was extended by Hull and De Rance to the Glacial deposits of Southern Lancashire generally, from the sea to the Pennines, and was adopted for the purposes of the Geological Survey.

In his paper Hull says that the sands are very variable in thickness, and that sometimes the Upper Boulder-clay may be seen coming down on to the Lower Boulder-clay. This he attributes partly to variation in deposition but mainly to erosion. As an example of variation in thickness, he describes the Drift as being over 200 feet at Kersall Moor, while four miles away, at Newton Heath and Openshaw, it is only 20 feet.

The Upper Boulder-clay, he says, occupies the districts, near Manchester, of Hyde, Denton, Newton, Failsworth, Oldham, and the

[1] These beds are numbered by Binney in the reverse order, the uppermost being numbered (1).

higher parts of Harpurhey and Blackley, Clifton, Kearsley and Little Lever.

In considering the evidence bearing on these classifications it is important to remember that the sands often contain lenticular beds of clay of fair thickness (10-15 feet) which are merely local features, dying out in all directions. The same applies to sand "pockets" in the clay. This fact was noted by Binney.[1]

Distribution of the Glacial Sands

The thick Glacial sands, called the "Middle Sands" by Hull, occupy the country in the north of Manchester from Boggart Hole Clough to Pendleton. In the centre of this area, in Kersall Moor and Higher Blackley, they have been reckoned to be over 200 feet thick. The boring on the east side of the lake in Heaton Park shows 106 feet of sands. One sunk near the Prestwich Asylum passed through 99 feet of sands containing a 31-foot clay-bed without reaching rock, and the shaft of Hugh o' th' Wood Colliery in Prestwich Clough gives 154 feet of alternating sands and clays.

If the sands are followed south from Boggart Hole Clough they are seen to be 42 feet thick at Crumpsall Old Workhouse. To the south of the workhouse a line of sewer sections along the Rochdale Road (Fig. 2, Pl. III.) shows these sands thinning out entirely in less than a mile.

Farther to the west the Glacial sands are well exposed in Alms Hill, where extensive excavations are being made. Just to the south of Alms Hill come the Queen's Road Clay Pits: here there is clay only. This complete change takes place in under a half-a-mile.

On the south side, therefore, the Glacial sands die out, and are replaced by clays.

To the east of Crumpsall Old Workhouse, and the south-east of Boggart Hole Clough, a similar replacement occurs, for in the Moston Collieries the sections show that the Drift is largely clay, with sand bands in it, the thickest of which is only 22 feet, while in the Failsworth area the section at Failsworth Pole proves clay with a 19-foot sand-bed, and one at Lymeditch shows nothing but clay. The two sections in the Prestwich area have alternating beds of clays and sands of almost equal thickness.

To the north of the Glacial sands, at Alkrington Colliery, which is about $2\frac{1}{4}$ miles from Heaton Park, the section is very similar to those at Moston, being clay with two sand bands, the thickest of which is 23 feet.

To the west of the typical sand area the section of the Whitefield Incline Pit has an 11-foot sand-bed.

In the North Pendleton district the sands are well shown in the Light Oaks Road—here a bore-hole was put down which proved 20 feet of sands without reaching rock. In Weaste, however, in the sandstone quarries overlooking the Irwell valley, the rock is covered

[1] *Mem. Lit. and Phil.*, II., Series 3, p. 464.

by about 3 feet of clay only. Between Light Oaks Road and Weaste various exposures show sandy Drift with lenticular beds of sandy marl.

These sections prove that the Glacial sands are absent in the areas surrounding the main outcrop; it may therefore be assumed that the sands form a huge lenticular patch, thinning out on all sides. It is true that the actual thinning is seen in one place only—that is in the Rochdale Road set of sewer sections, of which there are eight in a distance of a little over a mile. The first of these gives 60 feet of sand overlying clay, the second 59 feet of clay over more than 30 feet of sand, the third 56 feet of clay over more than 31 feet of sand, the fourth 66 feet of clay over 73 feet of sand, the sixth 87 feet of clay over more than 59 feet of sand, the seventh 81 feet of clay over 7 feet of sand, the eighth clay only. The first of these sections shows sand over clay, but, as the base of the clay is not reached, this may be only a lenticular band.

In spite of the fact that this is the only set of sections in which the actual disappearance of the sand can be followed in detail, the rapidity with which the sands disappear by Alms Hill, Light Oaks Road, Boggart Hole Clough, Heaton Park and the sections beyond these areas shows that there is replacement of sand by clay. This seems to show that the sands of Kersall Moor occur as a lenticular patch, and not as a definite layer under or overlying the neighbouring clays.

There are, of course, sand-beds in some of the sections in the districts surrounding the typical sand area; these may reach a thickness of twenty odd feet. The sections described are fairly far apart, but in places where sections are sufficiently close to one another to allow of detailed correlation it may be shown that sand-beds of more than 20 feet in thickness are purely local lenticles intercalated in the clays. Hence, in the absence of intervening sections, it is impossible to state definitely that the sands of Moston, Alkrington and Whitefield are continuations of the thick sands of Prestwich and Kersall, and in the absence of such evidence there is no ground for the belief that those sands constitute a definite stratum separating an Upper from a Lower Boulder-clay.

Evidence of the rapid incoming and dying out of sand-beds is given in several places. In the Fallowfield sewer cutting a lenticular bed of sand makes its appearance below the clay, attains a thickness of over 27 feet, and dies out again, all within a mile. A bore-hole in Newton Heath shows a sand-bed of 29 feet which is not seen in a second boring 150 yards to the east, nor in another 350 yards to the south. There are many other sections which show the irregularity of the deposits, but those mentioned are sufficient to demonstrate that sands more than 20 feet thick may be purely local in character.

Hull himself recognised the great variability of the Glacial deposits, and accounted for the absence of the "middle sands" in areas where he expected to find them by assuming that they had been eroded. Evidence of the lenticular character of the deposits as shown by the numerous sewer sections and the closely adjacent series

of bore-holes and shafts which have been made since Hull's day, together with the absence of sands in sections in the districts immediately surrounding the main sand area, points to the conclusion that the sands and clays of the Manchester district replace one another irregularly and do not present any definite sequence.

Unfortunately for the tri-partite classification of the Drift, those areas which have a thick top clay are without thick sands, while those which have true "middle sands" have no top clay. These sands, when they do occur, may overlie a clay-bed, as at the Heaton Park bore-hole, or they may come straight down on to the solid, as at Agecroft Bridge, Levinstein's Dye Works and Middleton Junction. The Glacial sands of this district cannot be said, therefore, to form a central layer between two clays.

Distribution of the "Upper" and "Lower" Boulder-clays

If it be accepted that the sands of Kersall Moor and Prestwich are nothing more than a huge lenticular patch, it follows of necessity that the clay-beds above and below these sands must be also local in character. Evidence of this can be obtained from sections and in the field.

Clay underlying the sands, which would be "Lower Boulder-clay," according to Hull's classification, is seen at the Heaton Park bore-hole, where it is 34 feet thick, and in the well section of the Crumpsall Old Workhouse, where it is 68 feet thick. These clays do not form a continuous basal layer, for they are absent at Middleton Junction in the north, at Messrs. Levinstein's works between the Crumpsall Old Workhouse and Heaton Park, and in the Rochdale Road sewer to the south, and on the west in the Irwell valley opposite to Agecroft Bridge, where the sands can be seen coming down on to solid rock.

The "Upper Boulder-clay" should, according to Hull, be present at Hyde, Denton, Failsworth, Oldham, the higher parts of Harpurhey and Blackley, Clifton, Kearsley and Little Lever.

From the sections given in the Hyde and Ashton-under-Lyne districts it will be seen that thick sands are absent at Hyde, Hyde Lane and Lordsfield, and that at Ashton Moss, where the sands are thick, the top covering of clay is only 12½ feet thick. In the sections given round Failsworth the sands are absent, as they are in Hollinwood, on the outskirts of Oldham. There are no sections giving details of the Drift in Clifton, but at Middleton there is no top clay. In the west, sections showing thick sands as at Stand Lane and Outwood have no overlying clay, and the Whitefield and Leigh pits have no sand. In the typical sand area, sections at Heaton Park, Crumpsall Old Workhouse and Messrs. Levinstein's works give no top clay, and it is also absent both in one at Prestwich Asylum, which passed through 99 feet of sand and clay without reaching rock, and in the shaft at Hugh o' th' Wood Colliery in Prestwich Clough.

In addition to these sections the top of the sands can be seen in Boggart Hole Clough, above Blackley, across Kersall Moor, at Alms

Hill and in Pendleton. In none of these places is there any definite covering of Boulder-clay. Near the 275-foot contour-line sandy clays occur locally; sometimes they have been dug out, showing a thickness of 5 to 10 feet. They are not brick clays, and can be seen thinning out on all sides.

It is therefore evident that round Manchester the thick sands have no covering of Boulder-clay and that they may or may not overlie clay, so that the clay deposits as well as the sands are lenticles.

The appended sections (pp. 10-13), to which reference has been made, are only a few of those which give a detailed account of the Drift, down to the rock. They include the only complete available records of borings in and around the neighbourhood of the Glacial sands, together with a few from the Hyde and Ashton-under-Lyne area, which were selected because, according to Hull, Upper Boulder-clay should have been visible in that district.

The other sections from the Manchester district, which cover an area about four times as large as that from which these were taken, show no sand-beds of any appreciable thickness.

Thickness of the Drift

As might be expected, the Drift is thinnest in the present river valleys. In Salford, Old Trafford and Hulme the general depth of the solid below the surface has not been yet shown to reach as much as 50 feet. An exception to this is seen in Trafford Park, where the bore-hole of the British Steel and Wire Company proved the depth of the pre-Glacial surface to be 94 feet below present sea-level, giving a thickness of 175 feet of Drift. It is impossible in this area to distinguish definitely between Glacial and post-Glacial deposits, though, judging from the recorded sections, it is highly probable that they are mainly alluvium.

East and north of this the Drift thickens considerably, though on the low ridge to the north of Fallowfield Station it is practically absent. In Levenshulme, by Albert Road and Stockport Road, it is over 50 feet thick, and at Levenshulme Print Works 82 feet. In the Openshaw, Ardwick and Bradford areas the thickness runs well above 50 feet. One boring in Openshaw shows 135 feet of Drift.

Round Hyde and Ashton the Drift thickens out; at Hyde, and in the Lordsfield and Ashton Moss Colliery sections it is over 100 feet thick, though at Hyde Lane it diminishes to 66½ feet. The Newton Heath sections give a thickness of about 100 feet. North of this the Glacial deposits again thicken. At the Moston Pits they are 170 and 174 feet, on Kersall Moor and Higher Blackley they have been estimated to be over 200 feet in thickness, and at Boggart Hole Clough they cannot be much less. At Failsworth and Hollinwood these deposits thin somewhat, being only about 100 feet thick, but at Heaton Park and Alkrington the thickness is 143 and 162 feet respectively, and at Middleton Junction 127 feet.

Farther west, at Prestwich, the asylum boring passed through

SECTIONS OF DRIFT IN AND AROUND THE AREA OF GLACIAL SANDS

Hyde	Hyde Lane Colliery	Ashton Moss Colliery, Ashton-under-Lyne	Lordsfield Colliery, Ashton-under-Lyne	Failsworth Pole	Lymeditch, Failsworth
		Sand and soil . 4			
		Clay . $12\frac{1}{2}$			
	Clay . 42		Clay . $43\frac{1}{2}$	Clay . 67	
Clay . . 70		Sand . $37\frac{1}{2}$			
	Sand and gravel . $22\frac{1}{2}$				Marl with few sand bands 112
		Clay . 6	Sand . 28		
Sand, loam and gravel 18				Sand . $19\frac{1}{3}$	
		Sand . 29			
				Clay . $18\frac{2}{3}$	
				Sand . $3\frac{1}{3}$	
Clay . . 36		Clay . $34\frac{2}{3}$	Clay . $101\frac{2}{3}$	Clay . $9\frac{2}{3}$	
			Gravel . $7\frac{2}{3}$		
Total thickness, 124	$66\frac{1}{2}$	$123\frac{1}{2}$	187	$118\frac{1}{3}$	112

All thicknesses given in *feet*

Sections of Drift in and around the Area of Glacial Sands

Bower Colliery, Hollinwood	Levinstein's Crumpsall Vale Dye Works, Blackley	Heaton Park Bore-Hole (East side of lake)	Whitefield, Incline Pit	Stand Lane Colliery, Meadow Pit, Radcliffe	Outwood Colliery
Clay . . $84\frac{1}{2}$	Sand . 77	Sand . 106	Clay . 32	Sand . $22\frac{1}{2}$	Sand . $53\frac{1}{4}$
Sand . . 3			Sand . 11		Clay . $31\frac{1}{6}$
			Clay . 23		Sand . 15
		Clay . 34			Clay . $32\frac{1}{4}$
		Sand and gravel 3			Gravel . 3
Total thickness, $87\frac{1}{2}$	77	143	66	$22\frac{1}{2}$	$124\frac{2}{3}$

All thicknesses given in *feet*

Astley Nook Colliery, No. 3 Pit	Sovereign Pit, Leigh	Limeside Bore-hole, Failsworth	Stockfield Colliery, Chadderton	Middleton Junction	Alkrington New Colliery, Moss Lane
Clay . . 4			Loam and sand 7	Sand . $21\frac{1}{2}$	Clay . $17\frac{1}{2}$
Gravelly marl $8\frac{1}{2}$	Clay . $31\frac{1}{2}$		Clay . 23	Clay . 9	Sand and loam . $23\frac{1}{2}$
			Sand . $12\frac{1}{3}$	Sand . 28	
			Clay . $21\frac{1}{4}$		Clay . 31
		Clay . 136		Clay . $5\frac{1}{6}$	
				Sand . $30\frac{2}{3}$	Sand . 15
				Clay . $12\frac{1}{2}$	
				Sand . 17	Clay . 66
		Gravel, clay & sand 4		Clay . . $2\frac{3}{8}$	
Total thickness, $12\frac{1}{2}$	$31\frac{1}{2}$	140	$63\frac{1}{2}$	127	153

All thicknesses given in feet

Moston Old Pit	Moston Colliery, No. 3 Pit	Crumpsall Old Workhouse Well	Prestwich Asylum Annex	Hugh o' th' Wood Colliery, Prestwich Clough	Park Colliery, Oldham
Clay . . 25	Clay . 37	Clay . 5	Sand . 37	Soil . 9	Clay . 24
Sand . . $5\frac{2}{3}$		Sand . 42		Sand . 33	Sand . 7
Clay . . $32\frac{1}{2}$	Sand . $22\frac{1}{2}$	Clay . $43\frac{1}{2}$	Clay . 31	Clay . 31	Clay . 63
Sand . . 14			Sand . 16	Sand . 16	
Clay . . $42\frac{2}{3}$	Clay . 90	Sand . $9\frac{1}{2}$	Clay . 10	Clay . $17\frac{1}{2}$	Sand . 6
		Clay . 25	Sand . 5	Sand . 11	
Sand . . $15\frac{1}{2}$				Clay . $10\frac{3}{4}$	
				Gravel . $5\frac{1}{2}$	
Clay . . $22\frac{1}{2}$	Sand and gravel . $21\frac{1}{3}$			Clay . 18	
Gravel . . 16				Clay . . 4	
Total thickness, 174	171	125	Rock not reached	$156\frac{1}{4}$	100

All thicknesses given in *feet*

SECTIONS OF DRIFT IN AND AROUND THE AREA OF GLACIAL SANDS

Astley Nook Colliery, No. 3 Pit	Sovereign Pit, Leigh	Limeside Bore-hole, Failsworth	Stockfield Colliery, Chadderton	Middleton Junction	Alkrington New Colliery, Moss Lane
Clay . . 4			Loam and sand 7	Sand . $21\frac{1}{2}$	Clay . $17\frac{1}{2}$
Gravelly marl $8\frac{1}{2}$	Clay . $31\frac{1}{2}$		Clay . 23	Clay . 9	Sand and loam . $23\frac{1}{2}$
			Sand . $12\frac{1}{3}$	Sand . 28	
			Clay . $21\frac{1}{4}$	Clay . $5\frac{1}{6}$	Clay . 31
		Clay . 136		Sand . $30\frac{2}{3}$	Sand . 15
				Clay . $12\frac{1}{2}$	
				Sand . 17	Clay . 66
				Clay . . $2\frac{2}{3}$	
		Gravel, clay & sand 4			
Total thickness, $12\frac{1}{2}$	$31\frac{1}{2}$	140	$63\frac{1}{2}$	127	153

All thicknesses given in *feet*

SECTIONS OF DRIFT IN AND AROUND THE AREA OF GLACIAL SANDS

Moston Old Pit	Moston Colliery, No. 3 Pit	Crumpsall Old Workhouse Well	Prestwich Asylum Annex	Hugh o' th' Wood Colliery, Prestwich Clough	Park Colliery, Oldham
		Clay . 5		Soil . 9	
Clay . . 25					Clay . 24
	Clay . 37	Sand . 42	Sand . 37	Sand . 33	
Sand . . $5\frac{2}{3}$					Sand . 7
Clay . . $32\frac{1}{2}$	Sand . $22\frac{1}{2}$		Clay . 31	Clay . 31	
Sand . . 14		Clay . $43\frac{1}{2}$			Clay . 63
			Sand . 16	Sand . 16	
Clay . . $42\frac{2}{3}$	Clay . 90	Sand . $9\frac{1}{2}$	Clay . 10	Clay . $17\frac{1}{2}$	Sand . 6
		Clay . 25	Sand . 5		
				Sand . 11	
Sand . . $15\frac{1}{2}$				Clay . $10\frac{3}{4}$	
				Gravel . $5\frac{1}{2}$	
Clay . . $22\frac{1}{2}$				Clay . 18	
	Sand and gravel . $21\frac{1}{3}$				
Gravel . . 16				Clay . . 4	
Total thickness, 174	171	125	Rock not reached	$156\frac{1}{4}$	100

All thicknesses given in *feet*

99 feet of sands and clays, while at Hugh o' th' Wood Colliery in Prestwich Clough the shaft section shows a thickness of 156 feet.

Viewed broadly, therefore, the Drift around Manchester is thickest on the north and east, and thins to the south and west.

Present Topography and its Relation to the Drift

The physical map of Manchester, Pl. I., contoured to every ten feet shows remarkable diversity in the character of the surface in different areas. In the north-west the surface is very irregularly broken. In the south and east the contours run very smoothly north-west to south-east. Up to the 200-foot line the surface slopes gently to the River Irwell. From the 200- to the 250-foot contours the gradient increases. Between the 250- and 350-foot lines occurs another belt of more level land. The most striking feature of the map is the deeply trenched character of the valleys, which in the north-west about Kersall and Prestwich entirely change the nature of the surface. Instead of the regular contours of the south and east, the ground shows a relatively high sand plateau, deeply dissected on the margins by a series of ravines. On the right bank of the Irwell the ground rises from the river steeply, and relatively unbroken.

Outside this area of irregular surface the levels stretching from south-west to north-east are only cut by the valleys of the Irk and Medlock. In the north-east, by Oldham, the latter river has trenched deeply into the solid rock.

Comparison of the physical map with one showing Drift thickness makes it clear that the area of broken country does not coincide with that of maximum Drift thickness; but if the comparison be made with a map showing the distribution of the sands and clays it becomes evident that the irregular surface occupies the same position as the Glacial sands, which stretch from Boggart Hole Clough across Prestwich to Pendleton.

It is quite natural that the rivers should cut deep gorges here, as the loose nature of the sands makes erosion easy; while on the east, where the almost equally thick deposits of Moston, Newton Heath the Ashton occur, the heaviness of the clay would prevent such rapid wearing.

The Pre-Glacial Surface

Unfortunately the records of the depth of the solid rock below the surface are too few and scattered to make it possible to draw a map of the pre-Glacial surface, except in the area of central Manchester and as far to the south as Alexandra Park.

This map, reproduced in Pl. II., shows that there is no correspondence between the present and pre-Glacial river valleys. One pre-Glacial valley is clearly seen near the centre of the map, where the pre-Glacial contours, which are marked in thick lines, trend from S.S.W. to N.N.E. This valley can be traced upwards from Brook's

Bar, past the junction of Cornbrook Street with Chorlton Road to the east of Oxford Road Station and Manchester Town Hall, across Piccadilly and between Rochdale Road and Oldham Street. Reference to the map will show that there is a hill of some 120 feet in height, forming the western side of this valley. The highest part of this hill runs from just south of Albert Square to the north angle of Central Station, the pre-Glacial surface in general rising from the old valley-bed towards the present channel of the Irwell. On the eastern side of the same ancient valley is a hill of similar height under London Road Station and its neighbourhood, and across this hill the Medlock is now cutting its way, as mentioned by Mr. Charles Roeder in his description of the Oxford Road sewer.[1]

This pre-Glacial valley is joined, just to the north of Brook's Bar, by another coming in from the east. This second valley can be traced upwards from the neighbourhood of Brook's Bar to the south of the Royal Eye Hospital and across Plymouth Grove Recreation Ground. It may possibly be connected with one which lies near the Levenshulme Print Works.

These two pre-Glacial valleys which unite near Brook's Bar presumably open into a deep valley across Trafford Park, the presence of which is certainly indicated by the boring of the British Steel and Wire Company, to which reference has already been made, as well as by the channel exposed at Salford Racecourse in the cutting of the Ship Canal.[2] The information concerning this latter valley is insufficient for mapping it ; it probably ran from north-east to south-west, as on such a line bore-holes give greater depths in the rock surface than those on either side. The present bed of the Irwell is unrelated to this deep valley—this is clearly seen in the section, Pl. III., Fig. 3, which shows the Irwell cutting its valley in the rock which rises steadily to the west of the Brook's Bar and Piccadilly valley as far as the Irwell. The most remarkable feature of this valley is its great depth. At Trafford Park it is 94 feet below O.D. As the fall of the river in pre-Glacial times from this point to its mouth cannot have been much less than it is now, this depth means that there has been an alteration in the height of the surface of about 178 feet since pre-Glacial times.

A similarly deep valley has been described by Mr. Mellard Reade [3] in the neighbourhood of Widnes. Here the valley is 141 feet below O.D. and 163 feet below the surface. Allowing for the fall of the river to be the same from Widnes to the sea in pre-Glacial and present times, these figures give an alteration of 185 feet in level since pre-Glacial days. Another part of this buried valley is described by Mr. Hunter [4] as being 120 feet deep. This is at Latchford, near Warrington. Each of these deep channels, at Old Trafford, Latchford and Widnes, lies in the present river valley, but is not coincident with the existing river-bed.

[1] *Trans. Manc. Geol. Soc.*, XX.
[2] Hunter, C. E. *Trans. Manc. Geol. Soc.*, XVII.
[3] *Proc. Liv. Geol. Soc.*, II.
[4] *Trans. Manc. Geol. Soc.*, XVII.

It has usually been assumed that the surface features of the pre-Glacial land have been obscured by the Glacial deposits, which have filled up the valleys, levelling-up the surface generally, and that it is through these deposits that the rivers are now cutting their valleys. The absence of relationship between the pre-Glacial and present contours bears out this assumption. But it may be seen that on the whole the pre-Glacial surface was smoother than the present one. This is only to be expected, as the elevation of the land and the addition of the Drift to the old surface would naturally give the streams renewed powers of vertical erosion, so causing them to have more deeply entrenched valleys.

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PROCEEDINGS

OF

THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.

Ordinary Meeting, October 2nd, 1917.

The President,

MR. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

A vote of thanks was accorded the donors of the books upon the table.

The President then delivered his Inaugural Address, in which he gave a sketch of the very important work which had been done in the Society since its inauguration in 1781.

The Address is printed in full in the *Memoirs*.

General Meeting, October 16th, 1917.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

Miss GRACE WIGGLESWORTH, M.Sc., Botanical Department of the Manchester Museum, The University, Manchester; Mr. FRED WILKINSON BARWICK, Manager of the Manchester Chamber of Commerce Testing House, Royal Exchange, Manchester; Mr. Kenneth Lee, of Messrs. Tootal Broadhurst, Lee & Co. Ltd., Oxford Road, Manchester; and Mr. ALFRED J. KING, Elleray, Windermere; were elected Ordinary Members of the Society.

Ordinary Meeting, October 16th, 1917.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

A vote of thanks was accorded the donors of the books upon the table.

Mr. D. WARD CUTLER, M.A., read a paper entitled:—

"Natural and Artificial Parthenogenesis in Animals."

This paper is printed in full in the *Memoirs*.

General Meeting, October 30th, 1917.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

Rev. J. J. INGRAM, M.A. (Cantab), Science Master, St. Bede's College, Manchester, was elected an Ordinary Member of the Society.

Ordinary Meeting, October 30th, 1917.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

During the meeting a valuable gift to the Society was made by Mr. Henry Boddington, of Pownall Hall, who presented the original painting by Ford Madox Brown for the fresco in the Manchester Town Hall, depicting Dalton engaged in collecting marsh gas from a pool.

It was unanimously resolved that the best thanks of the Society be accorded to Mr. Boddington, for his very valuable and appropriate gift.

The following account of the picture is taken from the official descriptions of the Mural Paintings in the Town Hall:—

> **"Panel No. 12.—Dalton Collecting Marsh-Fire Gas.** John Dalton, inventor of the Atomic Theory, was born at Eaglesfield, near Cockermouth, in Cumberland, September 5th, 1766. As early as when only twelve he started a school in partnership with a brother only a few years older. The stronger pupils, it is stated, would challenge Dalton to fight

on his offering to correct them. For many years of his life he maintained himself, in Manchester, by school teaching, but this laborious, if honourable, occupation did not hinder him from indulging in the most abstruse and far reaching speculations and researches; the result being that the Manchester schoolmaster, alone and unassisted, made himself the father of modern chemistry—that is if chemistry is one of the exact sciences and not a succession of independent experiments. How the idea of the Atomic Theory first presented itself to his mind it would be interesting to know, but we know very little of it. All we hear is, that it occurred to him as required, in order to explain certain remarkable phases of matter, which combines in some proportions and not in others. Once that idea had taken hold of his mind, he never abandoned it till he had worked it out. The natural gases presented the readiest mode of investigation; so he is represented as collecting marsh-fire gas, one of the natural and primitive forms of gas. The mode of getting it is the usual one of stirring up the mud of a stagnant pond, while an assistant (in this case a farmer's boy) catches the bubbles, as they rise, in a wide-mouthed bottle, having a saucer ready to close up the mouth under the water when the bottle is full. A group of children are watching him, and the eldest, who has charge of them, is telling the little boy who is bent on catching sticklebacks that 'Mr. Dalton is catching Jack o' Lanterns'—marsh-fire gas being, when on fire, the substance *the Will o'the Wisp* is composed of . . . . "

Hon. Professor W. BOYD DAWKINS, M.A., D.Sc., F.R.S., read a paper entitled :—"**The Organisation of Museums and Galleries of Art and Technology in Manchester.**"

This paper is printed in full in the *Memoirs*.

General Meeting, November 13th, 1917.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

Dr. GEOFFREY MARTIN, Ph.D., F.I.C., F.C.S., Head of the Research Department of the Co-operative Wholesale Society, Ltd.; Mr. WILLIAM HEAP HOLLAND, Spinner, The Cottage, Mottram Road, Alderley Edge, ; and Miss WINIFRED CROMPTON, Assistant Keeper in Egyptology, The Manchester Museum, The University, Manchester; were elected Ordinary Members of the Society.

Ordinary Meeting, November 13th, 1917.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

A vote of thanks was accorded the donors of the books upon the table. These included a number of Natural History publications of the British Museum.

Professor S. J. HICKSON, M.A., D.Sc., F.R.S., communicated a paper by Miss CONSTANCE LIGHTBOWN, M.Sc. on "**The Siphonozooids of the Sea-pens.**"

This paper appears in full in the *Memoirs*.

Professor F. E. WEISS, D.Sc., F.L.S., F.R.S. then read a paper on the "**Regional Distribution of the Native Flora of Teneriffe,**" by Dr. J. H. SALTER.

This paper will also be printed in the *Memoirs*.

Ordinary Meeting, November 27th, 1917.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

Hon. Professor W. BOYD DAWKINS, M.A., D.Sc., F.R.S., exhibited and described "**Examples of Pre-Roman bronze-plated iron from the Pilgrim's Way.**"

Professor BOYD DAWKINS, exhibited an iron snaffle-bit, an iron harness-ring, and an iron hub of a wheel, covered with a thin layer of bronze, discovered in 1895, on the site of a village in Bigbury Wood, about two miles due West of Canterbury. The village is of Prehistoric Iron Age, and is traversed by the Pilgrim's Way, and has yielded a considerable number of implements to be seen in the Manchester Museum. Of these the three above mentioned are of peculiar interest, because they show that the art of plating iron with bronze was known at that remote period, ranging indefinitely backward from the Roman conquest. The plating is very thin and beautifully executed, and more particularly that of the iron ring, in which the bronze surface reproduces exactly the effect of a covering of leather stitched on an iron ring. With regard to the question as to how the plating was done, Dr. E. Newbery has suggested that it might have been effected either by plunging the carefully cleaned iron into molten bronze, or by heating the iron in a furnace in which bronze was being made.

The implements found along with the plated articles consist of iron spears, axes, adzes, hammers, ploughshares, billhooks and sickles, of the types found in settlements elsewhere of the same age, such as Hunsbury near Northampton, and the Lake Village of Glastonbury. In addition to these there were also fetters and a chain for a chain-gang of six, with six rings to put round the neck.

Similar bronze-plated iron articles have been met with elsewhere. In a cemetery of the Prehistoric Iron Age at Aylesford, in the neighbourhood of the Pilgrim's Way, north of Maidstone in the valley of the Medway, similar plating is to be seen on the hoops of a wooden bucket. The metal work is of beautiful design with the "late Celtic flamboyants," and similar to those on scabbards at La Tène in Switzerland. The date of Aylesford is fixed by Sir Arthur Evans to be from about 100 B.C., down to the Christian Era. Iron-plated articles also occur in settlements and burial places of the same age, in various parts of Britain. A snaffle-bit, for example, found in Hunsbury Camp, near Northampton, closely resembles that on the table. The trappings of the horses, and the metal work of the wheels, found in the "chariot burials" in Yorkshire, is of the same elaborate type.

From the wide range of this art in Britain and on the continent, it may be inferred that it was introduced from the latter, and was afterwards practised in our islands. It was probably brought into Kent by the invading Belgae, and into Yorkshire by the Parisii, whose name still survives in Paris, their ancient land.

We may further note that the Pilgrim's Way, proved by its passage through Bigbury Camp to be Prehistoric, forms a part of the network of roads in the Prehistoric Iron Age, affording free communication between the various settlements,—Manchester, York, Durham, Hunsbury (Old Northampton), Bath, the Lake Village of Glastonbury, Old Sarum, and the camps of the downs of Berks, Wilts, and Dorset.

Mr. R. L. Taylor, F.I.C., F.C.S., then read a paper on "**The Effect of Light on Solutions of Bleaching Powder.**"

Experiments were described in which solutions of bleaching powder, differing in concentration and prepared in different ways, were exposed to diffused daylight and to intermittent bright sunlight, while other similar solutions were kept in the dark. Some of the experiments extended over fifteen months.

It was found that solutions exposed to sunlight decomposed quite rapidly, those exposed to diffused daylight much more slowly, while dilute solutions (one per cent.) kept in the dark remained quite unaltered for the whole period of fifteen months. A solution five times the strength of the latter, however, did undergo some decomposition, losing about 20 per cent. of its available chlorine even when kept in the dark. Solutions exposed to diffused daylight lost from

70 to 80 per cent. of their available chlorine in fifteen months, while those exposed to intermittent sunshine lost from 80 to 99 per cent. in twelve weeks. It was found, as was anticipated, that the amount of free lime present in the solutions had considerable influence on the rate of decomposition,—the smaller the proportion of free lime the greater the decomposition.

It was also found that the solutions which decomposed did not, as might be expected, decompose entirely in the normal way (the hypochlorite changing into chlorate and chloride), but in all cases there was a considerable loss in the total oxidising power of the solutions, due to the evolution of free oxygen.

General Meeting, December 11th, 1917.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

Rev. J. C. COOKE, St. Bede's College, Manchester; and Mr. J. WILFRID JACKSON, F.G.S., The Manchester Museum, The University, Manchester; were elected Ordinary Members of the Society.

Ordinary Meeting, December 11th, 1917.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

A vote of thanks was accorded the donors of the books upon the table.

Professor W. W. HALDANE GEE gave a short description of the **Exhibits of Diagrams, Manuscripts, Apparatus, and Books**, which chiefly related to **John Dalton** and **William Sturgeon**.

The Society possesses three of the portable electric kites designed by Sturgeon for use in investigations relating to atmospheric electricity. Two of these are made of calico and one measures 2 feet 8 inches by 2 feet 10 inches; and the other 3 feet 9 inches by 2 feet 10 inches; each possesses an arrangement of braces so as to relieve the wooden stretchers as much as possible from the strain produced by the wind.

The third kite, which is not complete, is made of "sarsenet." These were used in conjunction with a Leyden jar which could be charged by the atmospheric electricity. Descriptions of some of the experiments are given in a manuscript in the Society's possession.

The following is an example of one of the records:—

> "Friday, May 22nd, 1829. Barrack Field, 2 p.m. Gentle North-East Wind—some clouds to windward—Thermometer—in the sun, 78°, in the shade, 69°.—Barometer, 29·3.—Light Kite—300 yards string—floated high—Electricity positive. Steel needle feebly magnetised by the discharge of the Leyden Jar."

At the time these experiments were made Sturgeon was in the Royal Artillery at Woolwich; he subsequently lectured at the Royal Victoria Gallery of Practical Science in Manchester, and lectures given there on Galvanism and Electricity were published in 1842 and 1843. He also gave popular lectures in the district and some of his lecture syllabuses are exhibited in the Society's house. He edited the "Annals of Electricity," and issued in a large volume an account of his researches; these publications, which are in the Society's Library, were exhibited.

The Memorials of Dalton included his lecture diagrams, optical apparatus used at his popular lectures, his herbarium, laboratory note books, a complete set of account books, letters, and published works.

There was also an exhibition of early types of microscopes, which included the microscope designed by Culpeper and Scarlet in 1750—a very primitive instrument—made of wood with cardboard tubes; a microscope made by Adams in 1776 with a cog wheel to incline the instrument at a convenient angle; a reflecting microscope of Goring—described by Goring and Pritchard in 1837 in "Micrographia"; and a microscope used by John Dalton, recently presented to the Society.

Ordinary Meeting, January 8th, 1918.

The President,

Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

A vote of thanks was accorded the donors of the books upon the table. These included "Britain's Heritage of Science," by A. Schuster and A. E. Shipley, and "Overvoltage Tables," Parts i, ii, iii, and iv, by E. Newbery.

The following resolution was passed unanimously :—

"This meeting of the Literary and Philosophical Society of Manchester desires to give the most public expression of its profound sense of the humiliation wantonly imposed on the Nation by the reported action of the Government in wilfully submitting the priceless treasures of the British Museum to the certainty of irreparable damage."

Mr. T. A. COWARD, F.E.S., F.Z.S. (Vice-President) then took the chair, and the President, MR. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C. read a paper entitled—"**Somatose.**"

This paper is printed in full in the *Memoirs*.

General Meeting, January 22nd, 1918.

The Vice-President,

Professor S. J. HICKSON, M.A., D.Sc., F.R.S., in the Chair.

Mr. JOHN MAYER LEES, F.C.A., Lymefield, Offerton, Stockport, was elected an Ordinary Member of the Society.

Ordinary Meeting, January 22nd, 1918.

The Vice-President,

Professor S. J. HICKSON, M.A., D.Sc., F.R.S., in the Chair.

Mrs. CRAVEN exhibited a portion of a piece of coal containing a quantity of galena.

Mr. J. WILFRID JACKSON, F.G.S., read a paper entitled :—"**The Association of Facetted Pebbles with Glacial Deposits.**"

This paper will appear in full in the *Memoirs*.

Professor S. J. HICKSON, M.A., D.Sc., F.R.S., then gave a short account of a paper written by the late Mr. EDWARD HALKYARD, and edited and revised by Mr. EDWARD HERON-ALLEN and Mr. A. EARLAND on "**The Fossil Foraminifera of the Blue Marl, Côte des Basques, Biarritz.**"

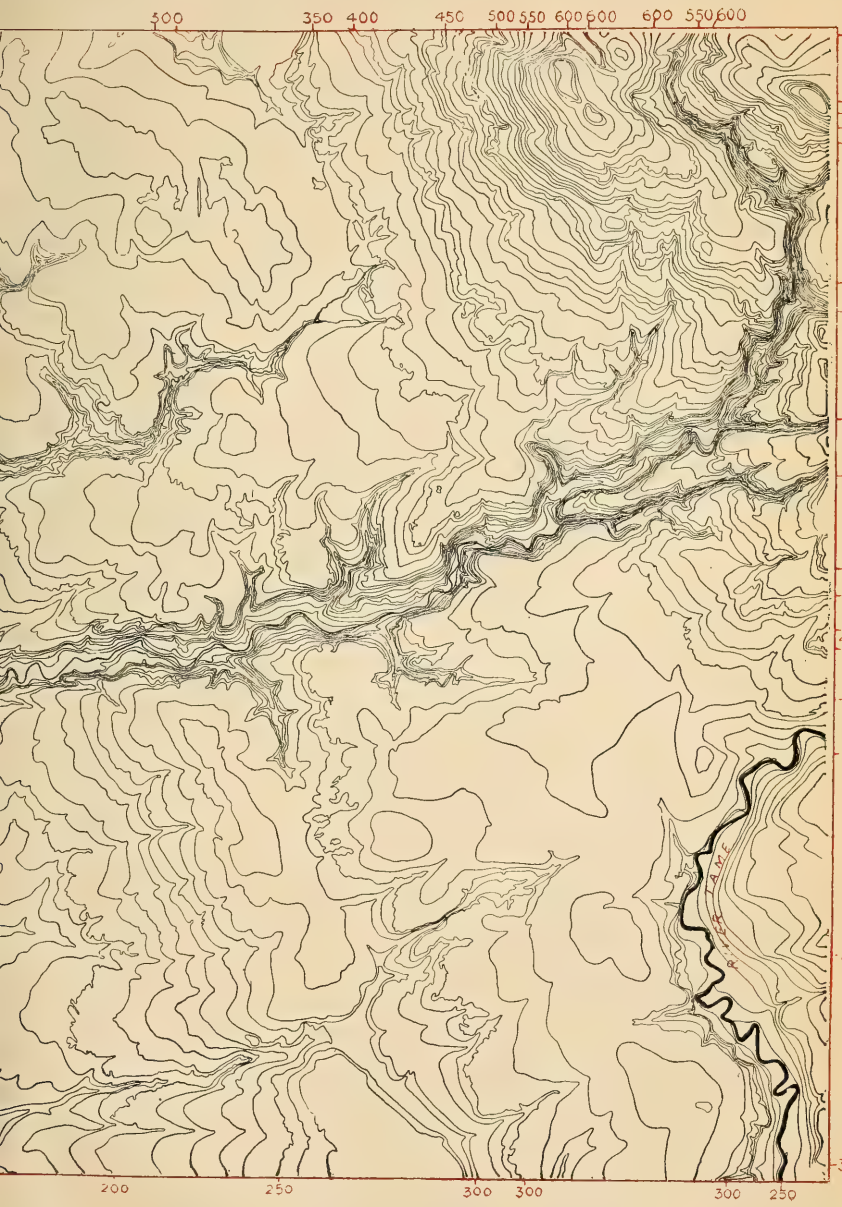
This paper will appear in full as Part II. of this volume.

TOPOGRAPHICAL MAP OF MANCHEST

Scale,

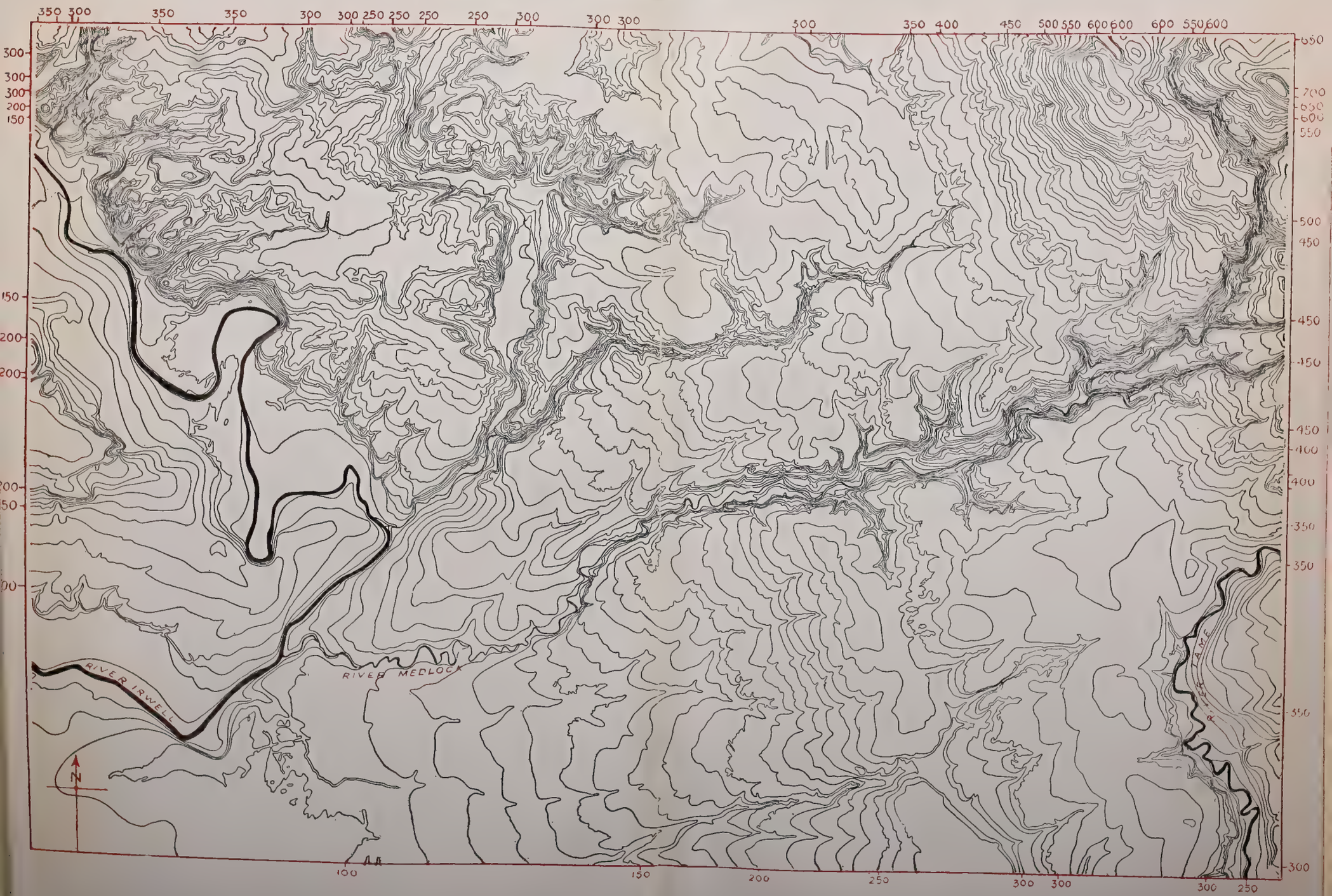
NTOURED AT INTERVALS OF 10 FEET.

= 1 mile.

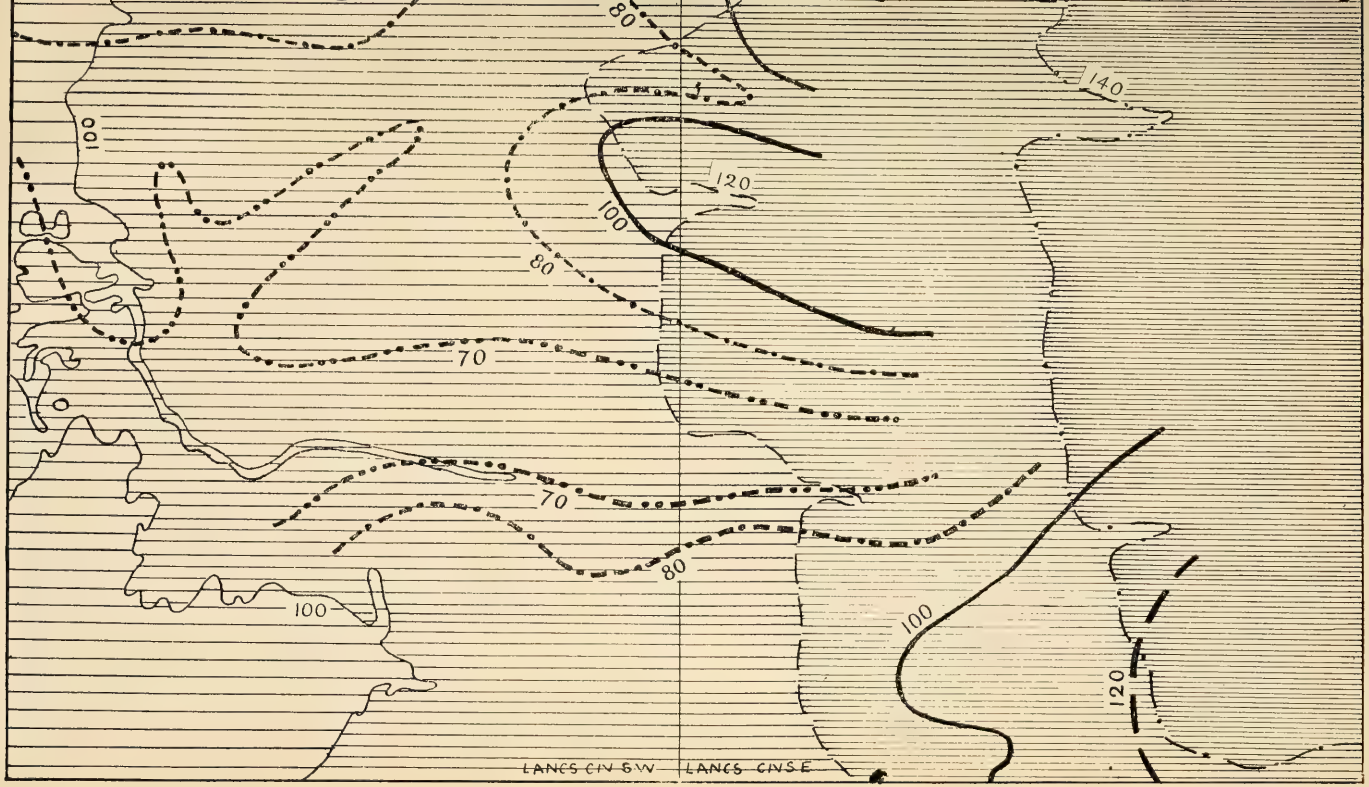


TOPOGRAPHICAL MAP OF MANCHESTER CONTOURED AT INTERVALS OF 10 FEET.

Scale, 1 inch = 1 mile.



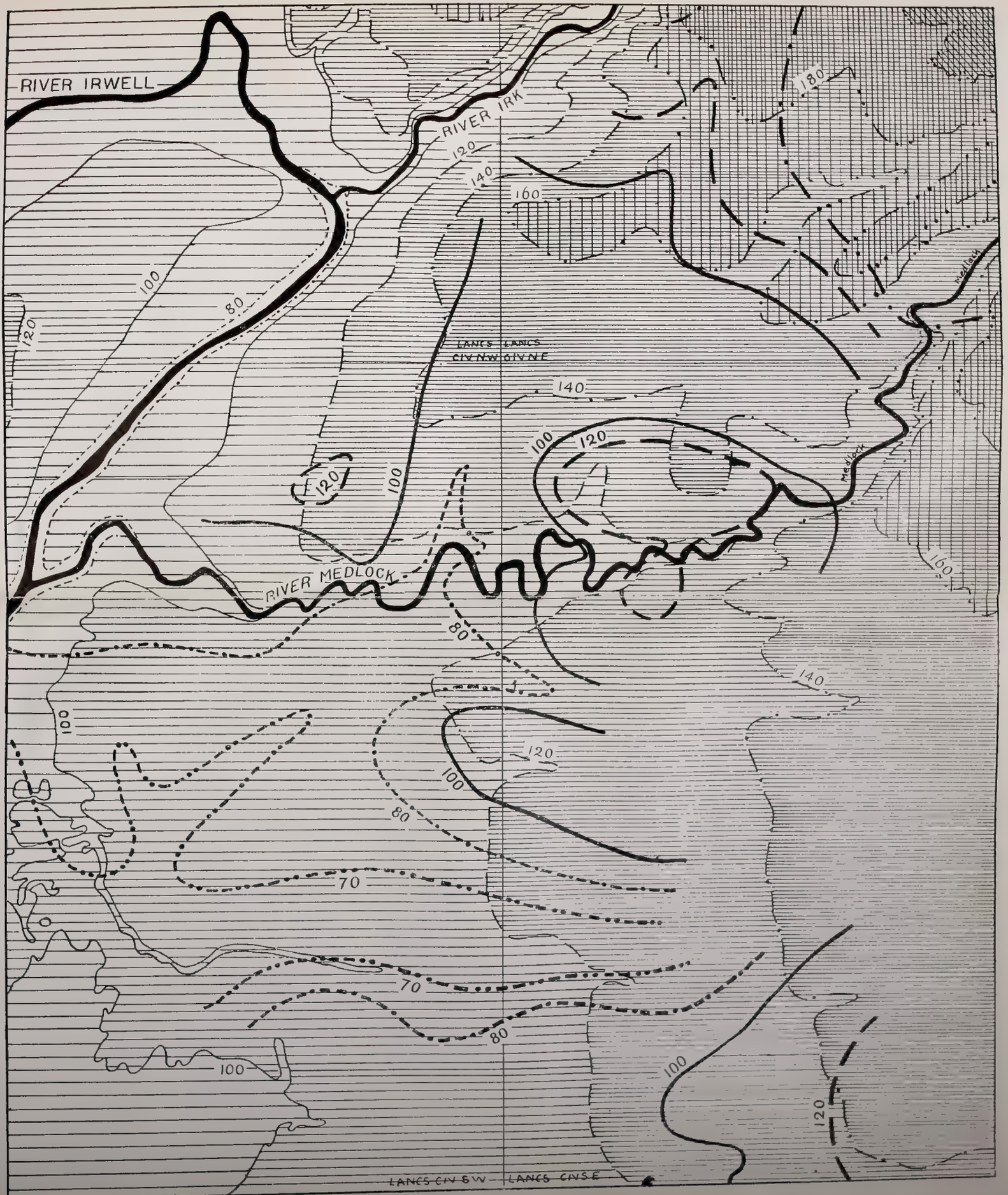
PLAN OF MANCHESTER SHOWING THE CONTOURS OF THE PRESENT SURFACE AND OF THE PRE-GLACIAL (SUB-DRIFT) SURFACE.



Scale: 3 inches to 1 mile.

Shaded contours = Present surface.
Thick contours = Pre-Glacial surface.

PLAN OF MANCHESTER SHOWING THE CONTOURS OF THE PRESENT SURFACE AND OF THE PRE-GLACIAL (SUB-DRIFT) SURFACE.



Scale: 3 inches to 1 mile.

Shaded contours = Present surface.
Thick contours = Pre-Glacial surface.

Fig. 1.—Diagram showing the variation of the Glacial D

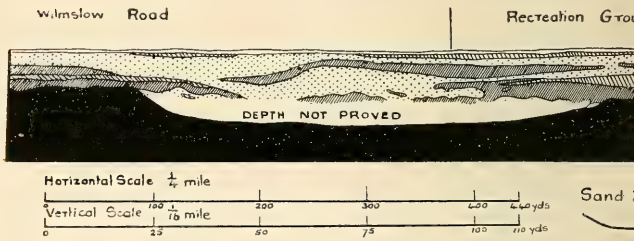


Fig. 2.—Section along Rochdale R

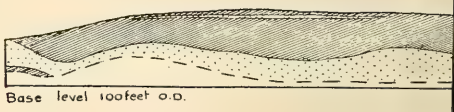


Fig. 3.—Diagram showing the Relation between

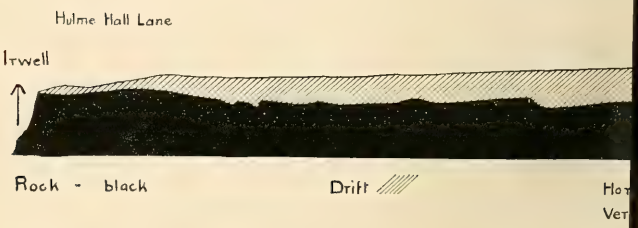
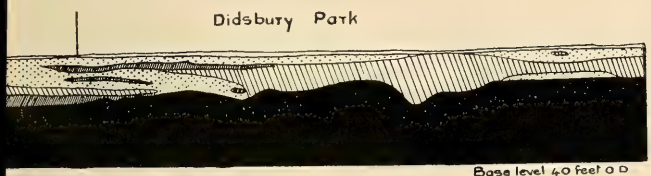


Plate III.

ts in the Wilmelow Road Sewer

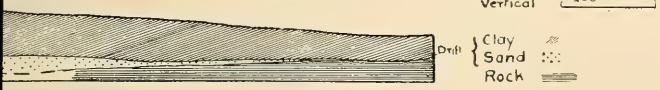


Clay Sandy Clay Rock in black

Drift

Sewer

S



rwell Valley and the Pre-glacial Surface

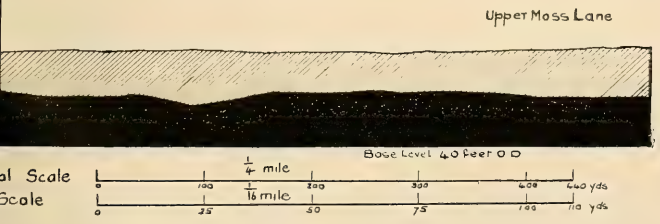


Fig. 1.—Diagram showing the variation of the Glacial Deposits in the Wilmslow Road Sewer

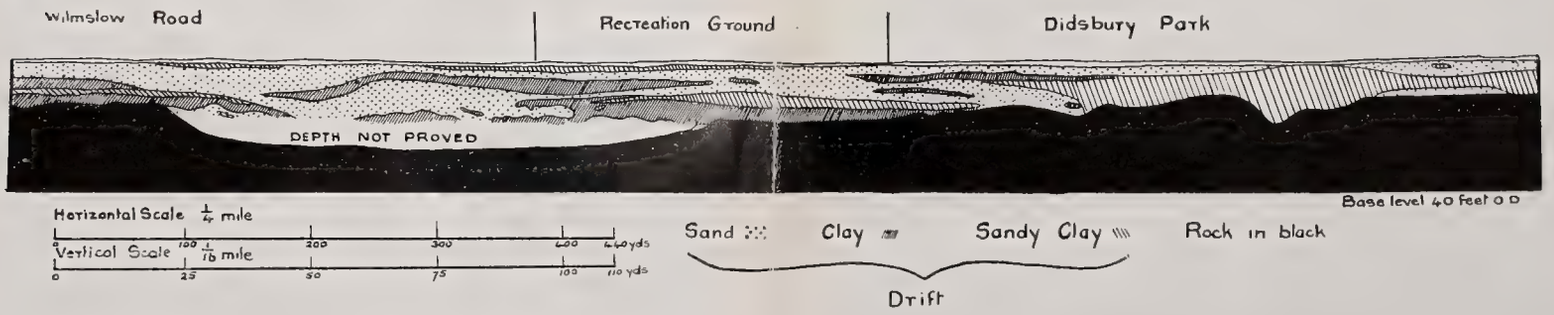


Fig. 2.—Section along Rochdale Road Sewer

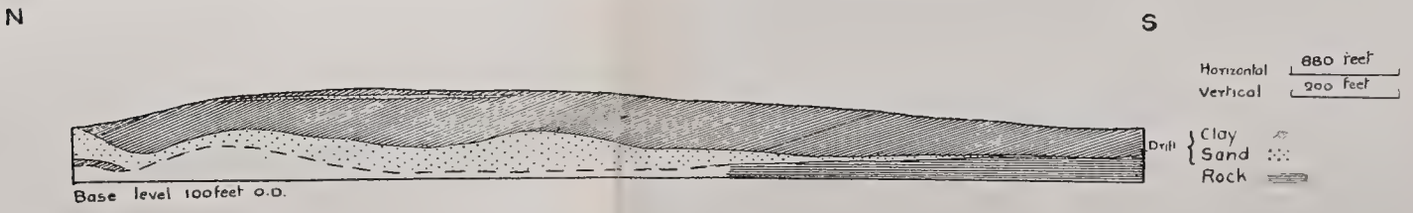
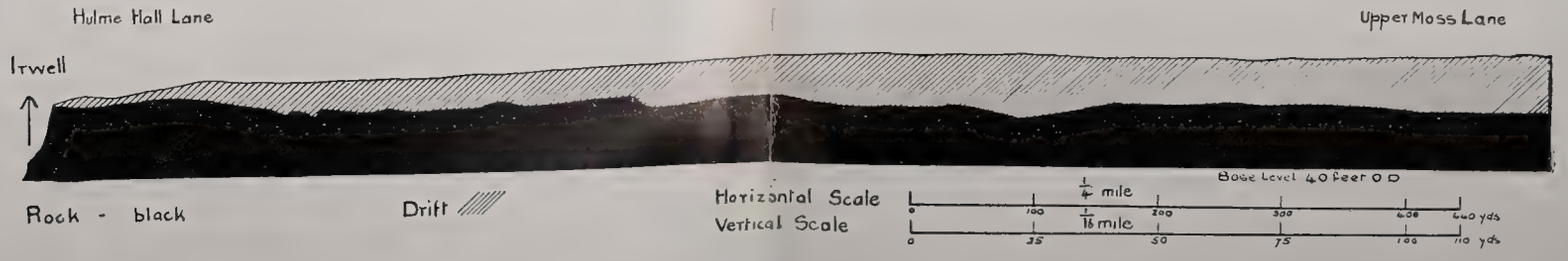


Fig. 3.—Diagram showing the Relation between the Irwell Valley and the Pre-glacial Surface



Ordinary Meeting, February 5th, 1918.

The President, Mr WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

Mr. G. P. VARLEY, M.Sc., and Mr. J. WILFRID JACKSON, F.G.S., were nominated Auditors of the Society's accounts for the Session 1917–1918.

Professor G. ELLIOT SMITH, M.A., M.D., F.R.S., read a paper by Captain Leonard Munn, R.E., entitled **"Ancient Mines and Megaliths in Hyderabad."** A paper entitled **"The Origin of Early Siberian Civilisation"** was also read by Professor G. Elliot Smith.

These papers will be printed in the *Memoirs*.

Ordinary Meeting, February 19th, 1918.

The President, Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

Mr. J. WILFRID JACKSON, F.G.S., exhibited specimens of **Planorbis dilatatus** (an American freshwater mollusc) recently obtained from the Bolton Canal, near Agecroft. This was first discovered in this canal in 1869, but apparently disappeared for many years.

Dr. J. STUART THOMSON, M.Sc., F.R.S.E., F.L.S., read a paper entitled **"The Occurrence of Cavernularia Lütkenii, *Köll*, in the Seas of Natal."**

This paper is printed in full in the *Memoirs*.

Mr. L. STANLEY JAST read a paper **"On the Necessity of a Technical Library for Manchester and District."**

Mr. Jast stated that a true library is a collection of books made productive, and implies properly constructed catalogues, careful selection of books, and skilled custodians.

A special library is such by virtue of the act that it covers a limited field. This, in the case of technical books, means the useful arts, which in these days are usually applied science.

A special collection, isolated from a general collection, loses a good deal of its value. Technology overlaps with pure science, with the fine arts, and with both sociology and history.

The need for a great technical collection for Manchester, with adequate equipment and staff, is urgent.

As a nation we have persistently ignored the fact that ideas, whether in the direction of discovery or in that of invention, are

not as a rule the result of practical work in the shop or laboratory. It has been well said that "ideas come to a man, not when his hands are full of things, but when his mind is full of thoughts," and in the main we get our ideas from books. The suggestion obtained in the library may be worked out in the shop or laboratory.

Manchester should lead in that provision of technical libraries which must form a not inconsiderable part of our equipment for shouldering our due share of the commerce of the world after the war.

Dr. F. E. Bradley, Dr. G. Hickling, Professor Hickson, Professor W. W. Haldane Gee, and Mr. Thomson took part in the discussion of this paper, and the following resolution was passed unanimously :—

> "That the Manchester Literary and Philosophical Society, being a Society founded in 1781 for the Advancement of Science, appeals to the Manchester City Council to establish a Technical Library for Manchester and District, which should contain, for easy reference, all the Technical Works and Periodicals published throughout the world.
>
> "An eminent member of this Society, the late Dr. Angus Smith, said, in 1881, 'Manchester is rich, but without Science it will not remain so,' and an up-to-date Technical Library in Manchester is urgently necessary for the full development of Technical Science in this district."

Ordinary Meeting, March 5th, 1918.

The President, Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

A vote of thanks was accorded the donors of the books on the table.

Mr. E. L. RHEAD, M.Sc.Tech., F.I.C., read a paper entitled: **"The Corrodibility of Cast Iron."**

The author pointed out that there was no intention to deal with the electrical conditions, state of passivity, or the formation of protective coatings of insoluble salts on the iron by the liquids in contact with the metal. The paper dealt with the effects of the impurities in producing during the solidification of the metal various solutions in which the impurities were concentrated. This was especially the case with the phosphide. The concentration depended on the lower melting point of the solution thus formed. Attention was also drawn to the production of graphite.

These last portions of liquid to solidify lead, by contraction and subsidence by gravity, to the formation of cavities, crevices, and cracks of capillary size, which in many cases communicate

and form channels by which the corroding liquid or gas penetrates to the interior, and this is intensified by alternate expansion and contraction due to heating and cooling, and by vibration. This increase is most pronounced where the continuity of structure and cohesion is least—*i.e.* at the graphite flakes. It was shown by photo-micrographs and actual specimens of corroded material, that the concentration occurs, and that corrosion follows these segregations and the graphite. Examples in which the graphite plate occupied the middle of the corrosion were pointed out.

Specific instances in which the failure of cast-iron vessels was due to the increase in volume resulting from the corrosion, and the influence of the structure due to the segregation and coarse graphite, were dealt with and specimens shown. Analyses and examinations showed that the collapse of the vessels was due to these causes.

Attention was also directed to the high silicon iron now used for chemical plant, and segregation was shown to take place to a marked extent. The author showed that the failure in many cases investigated was due to the presence of graphite and phosphide. Separated pellets of phosphide taken from cavities in metal containing 13.6 silicon and 0.41 phosphorus contained over 4.1 per cent. of phosphorus and only 10.45 of silicon. These were attacked while the silicon iron itself is but little affected. In a series of tests it was shown that, in the same metal, the amount of phosphorus removed by the corroding liquids employed was many times greater than the proportion in the mass of the metal, thus showing that the cavities and concentrations formed the line of attack, which led to the ultimate failure of the metal.

Ordinary Meeting, March 19th, 1918.

The President, Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

The President referred to the death, on March 12th, of Mr. George Stephen Woolley, who was elected a member of the Society in 1860.

Mr. Thomson exhibited two specimens of what were represented as minerals which had been washed down from a mountain in Angola (a province in West Africa, south of the Congo). The one was a cube of Iron Pyrites about a cubic inch covered with a hard layer of the proto and per oxides of iron about a quarter of an inch in thickness. The pyrites was free from arsenic.

The other was a specimen of what I found to be metallic iron associated with silicium and graphite, but containing no nickel, and which, it was suggested, might have been manufactured by the natives, and not native iron. This might possibly be so, but

against this is the fact that the specimen was comparatively brittle and could be pounded to a rough powder in an iron mortar. In the iron manufactured by natives the temperature obtainable by them would not be sufficiently high to reduce silica to the form of silicium, and the iron produced by them would be presumably anything but brittle. On dissolving the metallic iron in hydrochloric acid and treating the residue with caustic soda solution, hydrogen was liberated showing that the silicium was there in the elementary condition, which strengthens the assumption that this iron existed as native metallic iron.

Professor G. ELLIOT SMITH, M.A., M.D., F.R.S., read a paper on **"Race, Character, and Nationality."**

Professor G. Elliot Smith stated that the influences of race and heredity, geographical circumstances and language, though potent in various directions to affect the character and achievements of individuals and to play a part in the development of the true spirit of nationality in a community, are not the chief factors. The personal experience of each individual, his social environment and especially the traditions of his community, shape his outlook on life, determine his character and give specific directions to his inherited aptitudes. The most powerful forces that mould nationality and weld together a heterogeneous collection of people of varied origin, abilities and traditions, consist of historical circumstances, which provide the community with common aims and aspirations, common traditions and social fashions, common trends of thought and modes of behaviour. Such circumstances play a more vital part than mere race or hereditary aptitudes in the development of the spirit of nationality.

Ordinary Meeting, April 9th, 1918.

The President, Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

The following resolution was passed unanimously:—"This meeting of the Manchester Literary and Philosophical Society has heard with concern that the War Office proposes to demolish the two cottages by Stonehenge, which serve as the domiciles of the custodian and the police constable charged with the safe-keeping of the monument. As these are the only available cottages in the neighbourhood, the Society feels that such action may be fraught with perilous consequences and therefore begs leave to direct the attention of the Secretary of State for War, to the urgent necessity of taking adequate steps to protect this national monument from injury or defacement."

Mr. C. E. Stromeyer, M.Inst.M.E., M.Inst.C.E., made a short communication on "Long-Range Guns."

Mr. C. E. Stromeyer afterwards read a paper on "Ancient History: **"The Identification of Zophyrus."**

The paper deals with the betrayal of Egypt and of Babylon between the years of B.C. 525 to 517. Herodotus mentions both events, but no direct reference is made to them in the Bible, although Isaiah gives a most accurate description of the traitor. By combining his hints and the accounts by Herodotus and by the prophet Zachariah, the catastrophes of these few years are clearly revealed. It appears that a man whom the Egyptians called Phanes, and who was a highly placed official in the auxiliary forces of Amasis, King of Egypt, deserted to Cyrus, King of the Persians, and instructed them how to subdue Egypt. After the death of Cyrus, Cambyses his son, acting on his advice, with one blow at the Battle of Pelusium, crushed Egypt out of existence. Apparently the same man, known to Herodotus as Zophyrus, betrayed Babylon. He achieved this object by cutting off his nose and ears, and otherwise making himself the despised and rejected of men, deserting from the Persians to the Babylonians, and making them believe that he was a Persian nobleman, and that his indignities had been inflicted on him by Darius. He thus obtained control of the Army and of the Gates, and admitted the Persians. He was rewarded by the temporary ownership of Babylon, and the prophet Zachariah tells us that one year after the fall of Babylon, Zephaniah sent gold and silver to Jerusalem. But Zephaniah is a name which links together the other two, a probability calculation based on the Greek alphabet, showing that the chances are about 1000 to one that the three names are those of the same man.

This Zephaniah, alias Phanes, alias Zophyrus, seems to have perished in the Babylonian revolt, which occurred very soon after the above events. Isaiah refers to the despised of men as being dead.

Annual General Meeting, April 23rd, 1918.

The President, Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

The Annual Report of the Council and the Statement of Accounts were presented, and it was resolved:—

"That the Annual Report, together with the Statement of Accounts, be adopted, and that they be printed in the Society's *Proceedings*."

Mr. D. WARD CUTLER and Mr. J. WILFRID JACKSON were appointed Scrutineers of the balloting papers.

The following members were elected Officers of the Society and Members of the Council for the ensuing year :—

President: WILLIAM THOMSON, F.R.S.E., F.I.C., F.C.S.

Vice-Presidents: T. A. COWARD, F.Z.S., F.E.S.; W. W. HALDANE GEE, B.Sc., M.Sc.Tech., A.M.I.E.E.; SYDNEY J. HICKSON, M.A., D.Sc., F.R.S.; FRANCIS JONES, M.Sc., F.R.S.E., F.C.S.

Secretaries: R. L. TAYLOR, F.C.S., F.I.C.; GEORGE HICKLING, D.Sc., F.G.S.

Treasurer: W. HENRY TODD.

Librarian: C. L. BARNES, M.A.

Other Members of the Council: MARY MCNICOL, M.Sc.; FRANCIS NICHOLSON, F.Z.S.; E. L. RHEAD, M.Sc.Tech., F.I.C.; G. ELLIOT SMITH, M.A., M.D., F.R.S.; F. E. WEISS, D.Sc., F.R.S., F.L.S.; R. S. ADAMSON, B.Sc., M.A.

Ordinary Meeting, April 23rd, 1918.

The President, Mr. WILLIAM THOMSON, F.R.S.E., F.C.S., F.I.C., in the Chair.

A vote of thanks was accorded the donors of the books upon the table. These included "The Megalithic Culture of Indonesia," by W. J. Perry and "Shells as Evidence of the Migrations of Early Culture," by J. Wilfrid Jackson.

A paper entitled "**Radioactivity and the Coloration of Minerals,**" by Dr. E. NEWBERY and Mr. H. LUPTON, B.Sc., was then read.

This paper is printed in full in the *Memoirs*.

General Meeting, May 7th, 1918.

The President, Mr. WILLIAM THOMSON, F.R.S.E., F.I.C., F.C.S., in the Chair.

Miss MABEL BROOK, B.Sc., c/o Messrs Tootal, Broadhurst Lee Company Ltd., 56 Oxford Street, Manchester, was elected an Ordinary Member of the Society.

Ordinary Meeting, May 7th, 1918.

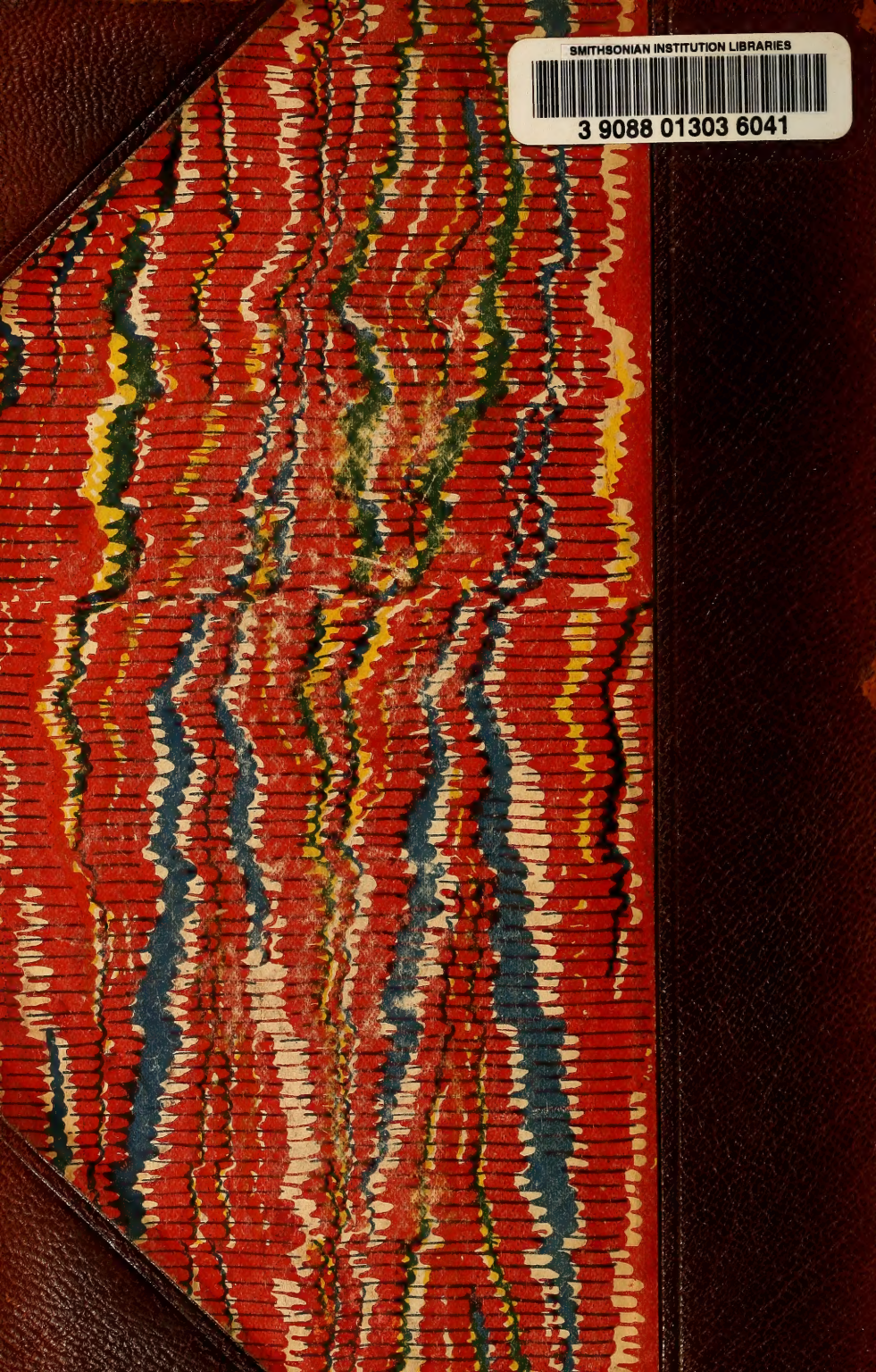
The President, Mr. WILLIAM THOMSON, F.R.S.E., F.I.C., F.C.S., in the Chair.

Mr. TAYLOR exhibited a notice of the meeting of the Society held on April 2nd, 1839, which was sent to Mr Just of Bury.

Professor WEISS exhibited a series of wools dyed with dyes obtained from British plants. This collection, which was prepared by Dr Plowright, is now in the possession of the Manchester Museum.

Miss M. C. MARCH, M.Sc., read a paper entitled **"The Glacial Deposits of Manchester."**

This paper is printed in full in the *Memoirs*.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